WHAT IS SPACE WEATHER AND WHO SHOULD FORECAST IT?

HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY, AND STANDARDS

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

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October 30, 2003

WHAT IS SPACE WEATHER AND WHO SHOULD FORECAST IT?

THURSDAY, OCTOBER 30, 2003

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY, AND STANDARDS,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 10 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Vernon J. Ehlers [Chairman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

What Is Space Weather and Who Should Forecast It?

Thursday October 30, 2003

10:00 AM – 12:00 PM
2318 Rayburn House Office Building (WEBCAST)

Witness List

Dr. Ernest Hildner
Director, Space Environment Center,
National Oceanic and Atmospheric Administration

Col. Charles L. Benson
Commander,
Air Force Weather Agency

Dr. John M. Grunsfeld
Chief Scientist,
National Aeronautics and Space Administration

Mr. John Kappenman
Manager,
Applied Power Systems, Metatech Corporation

Mr. Hank Krakowski
Vice President of Corporate Safety, Quality Assurance, and Security,
United Airlines

Dr. Robert Hedinger
Executive Vice President,
Loral Skynet

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HEARING CHARTER

SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY, AND STANDARDS

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

What Is Space Weather and Who Should Forecast It?

THURSDAY, OCTOBER 30, 2003
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On October 30, 2003 at 10:00 a.m., the House Science Committee's Subcommittee on Environment, Technology and Standards will hold a hearing to examine the space weather activities at the National Oceanic and Atmospheric Administration's (NOAA) Space Environment Center. The Space Environment Center (SEC) provides real-time monitoring and forecasting of solar and geophysical events. These events can: cause damage to communication satellites, electric transmission lines and electric transformers; interfere in ground-based communications with airline pilots; be fatal to astronauts on space flights and in the International Space Station; and potentially harm airplane passengers flying polar routes. SEC forecasts are used by the U.S. military, the National Aeronautics and Space Administration (NASA), NOAA itself, and by the industries mentioned above. For example, just last Wednesday (October 22), the SEC released two-day advanced warnings about an unusually large solar storm, which allowed electrical utilities, airlines, and spacecraft managers to take preventive action to minimize disruption of service due to the storm. (See attachment.)

The Air Force Weather Agency works closely with NOAA's SEC on the collection of space weather data through satellite and ground-based sensors and provides warnings tailored for specific military needs. The Air Force relies on the SEC for data analysis and overall forecasting. The Air Force and NOAA each contribute to the cost of sensors to monitor space weather, and NASA provides many of the satellites on which the sensors are carried.

In the House Fiscal Year (FY) 2004 Commerce, Justice and State (CJS) appropriations bill, SEC funding levels are below the Administration's request. The Senate CJS Appropriations Committee report includes the suggestion that the Air Force or NASA should take on the duties of predicting space weather and contains no funding for SEC. Thus, budget constraints could force the closure or reduction of these vital and unique services provided by NOAA's SEC. The Subcommittee wants to better understand the potential impact of the loss of SEC services.

The Subcommittee plans to explore several overarching questions, including:

1. Why do we need to understand and forecast space weather events?
2. What unique capabilities and expertise does NOAA's SEC provide? To what extent could the Air Force or NASA perform these duties?
3. What are the implications of closure or reduced activities of NOAA's SEC to the government and private sector?

Witnesses:

Dr. Ernest Hildner, Director, Space Environment Center, National Oceanic and Atmospheric Administration (NOAA), Boulder, Colorado. Dr. Hildner will provide an overview of the SEC, the services it provides and its collaborations with other federal agencies.

Col. Charles L. Benson, Jr., Commander, Air Force Weather Agency, Offutt Air Force Base, Nebraska. Colonel Benson will explain the mission of Air Force Space Weather Operations Center and the way the Air Force and NOAA work together on space weather prediction.

Dr. John M. Grunsfeld, Chief Scientist, National Aeronautics and Space Administration (NASA). Dr. Grunsfeld will discuss the effects of space weather on NASA operations.

Mr. John Kappenman, Manager, Applied Power Systems, Metatech Corporation, Duluth, Minnesota. Mr. Kappenman will discuss the effects of space weather events on electric power grid systems and how the loss of NOAA's SEC would affect this industry. Mr. Kappenman was formerly with Minnesota Power.

Captain Hank Krakowski, Vice President of Corporate Safety, Quality Assurance, and Security, United Airlines, Chicago, Illinois. Captain Krakowski will discuss how space weather events affect the airline industry, including air traffic control communications and human health concerns. He also will discuss how the loss of NOAA's SEC would affect United Airlines operations.

Dr. Robert Hedinger, Executive Vice President, Loral Skynet, Bedminster, New Jersey. Dr. Hedinger will explain the implications of space weather events for communications satellites and how the loss of NOAA's SEC would affect the commercial satellite sector.

Background

What Is Space Weather?

Space weather refers to conditions on the sun and in the solar wind, which can cause disturbances in the outer layers of the Earth's atmosphere. Highly energized particles from the sun disrupt the upper layers of the Earth's atmosphere, causing geomagnetic storms that result in increased radiation and rapid changes in the direction and intensity of the Earth's magnetic field. These conditions can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. Government and private sector organizations concerned with communications, satellite operations, electric power grids, human space flight, and navigation use space weather information.

History of NOAA's Space Environment Center

NOAA's Space Environment Center (SEC), located in Boulder, Colorado, began in the 1940's as a program to study short-wave radio propagation at the National Bureau of Standards (now known as the National Institute of Standards and Technology, or NIST). As the SEC expanded its scope to study the effects of solar weather on the Earth's atmosphere, the center moved into the Office of Oceanic and Atmospheric Research in NOAA, where it is currently located. The SEC consists of three divisions: research and development, space weather operations, and systems. The SEC has 54 NOAA staff and two Air Force liaisons in its Boulder office. In a 2002 report, the National Academy Sciences, called the work of the SEC "crucial."

NOAA's SEC collects, provides, and archives space environment data from its polar-orbiting and geostationary satellites, from other federal agencies, and through international data exchange. Forecasters at SEC provide space weather forecasts and warnings to users in government and industry and to the general public, while the Air Force and private sector users take these forecasts and tailor them for their organizations' specific needs. SEC's space weather operations division is the national and international warning center for disturbances in the space environment that can affect people and equipment. The effects of these disturbances are described in more detail below. The research and development division is home to the leading experts in space weather. They conduct research in solar-terrestrial physics, develop techniques for forecasting solar and geophysical disturbances, provide real-time monitoring and forecasting of solar and geophysical events, and prepare data to be archived by NOAA's National Geophysical Data Center.

Air Force Space Forecast Center

NOAA's SEC works closely with the U.S. Air Force's Space Forecast Center at Offutt Air Force Base in Nebraska, which provides space weather forecast services to U.S. military customers. The total budget for Air Force space weather efforts was $15.3 million in FY 2003. The Air Force provides two personnel who work at the SEC to ensure that this vital space weather information is fed smoothly to the Air Force, which then tailors it for military purposes. For example, NOAA's SEC may issue a warning that a geomagnetic storm will occur in the Earth's atmosphere at a certain time. The Air Force will use this information to make recommendations about military satellites that should be turned or powered down, or military operations that should be suspended until the storm passes.

NASA Operations

NASA requires information about space weather to make decisions regarding the space shuttle and International Space Station (ISS) operations. For example, astronauts conducting space walks could be killed if they were exposed to high levels of radiation. Additionally, astronauts inside the ISS may have to take special precautions during a solar storm. In fulfilling its research mission, NASA flies many of the sensors used to collect space weather data on its research satellites.

National Space Weather Program (NSWP)

Previous reviews of the space weather program have concluded that NOAA should continue to run the civilian space weather forecasting operation.

For example, in 1997, an interagency working group developed "The National Space Weather Program Implementation Plan," under which NOAA was to continue to run civilian space weather programs and the Air Force was to continue to run such programs for the military. The interagency group included NOAA, the National Science Foundation, the Department of Defense, NASA, the Department of Energy, the Department of the Interior, and the Department of Transportation.

Similarly, in its 2002 report, "The Sun to the Earth—and Beyond: A Decadal Research Strategy in Solar and Space Physics," the National Academy of Sciences recommended that NOAA not only continue to forecast space weather but that NOAA should do more to coordinate the development of the sensors that are used to make its forecasts. Specifically, the Academy recommended that NOAA and NASA initiate a plan to transition solar monitoring sensors from their current location primarily on research satellites to operational satellite programs.

The SEC Budget Situation

The Space Environment Center is funded through NOAA's Office of Oceanic and Atmospheric Research (OAR). In FY 2003, the SEC received $5.2 million (a reduction of $2 million below FY 2002 levels). For FY 2004, the Administration requested $8 million for NOAA's SEC. At this time, the FY 2004 appropriations process is ongoing in Congress. The House Commerce, Justice, State (CJS) bill, passed in July, provides $5.2 million for the SEC (same level as FY 2003). The Senate CJS bill, reported out by the full committee, recommends no funding for SEC and suggests that the Air Force or NASA should assume the responsibility of forecasting space weather. Funding for some of the sensors and satellites that provide data to the SEC is already provided by other agencies, such as NASA and the Air Force, but NOAA's SEC is the national center for data collection and forecasting of space weather events.

SEC Funding History 2002-Present (in millions of dollars)

FY2002 Enacted	FY2003 Request	FY2003 Enacted	FY2004 Request	FY2004 House bill	FY2004 Senate Committee Recommendation
$7.24	$7.78	$5.24	$8.02	$5.29	$0

Why Do We Need Space Weather Forecasts From NOAA's SEC?

Electric Power Grids

The first recorded evidence of space weather effects on technology was in 1859, when a major failure of telegraph systems in New England and Europe coincided with a large solar flare. More recently, on March 13, 1989, geomagnetically induced currents in Canadian transmission lines set off a cascade of broken circuits, causing loss of power for the entire Hydro-Quebec power grid. The blackout affected six million customers and cost Hydro-Quebec more than $10 million.

In 1998, a similar geomagnetic storm was headed for Earth. This time, thanks to data from new sensors and improved forecast models, NOAA's SEC forecasters were able to alert electric power customers 40 minutes before the storm hit the Earth. In response, electric power utilities diverted power and increased safety margins on certain parts of the grid to avoid stress on the power system.

Satellite Operations

In addition to electric power grid operations, human activities dependent on satellites are affected by space weather. This includes everything from communications to satellite-television. Research done at NOAA's SEC has helped provide the government and other satellite operators with data on storms to help understand whether a failed satellite was due to mechanical problems or space weather. Additionally, the satellite industry uses space weather forecasts to determine the timing of rocket

launches to avoid sending a multi-million dollar satellite into orbit at the peak of a solar storm.

Communications Satellites

Solar storms cause disturbances in the Earth's ionosphere that can affect the orbital path of low-orbit spacecraft, creating operational and tracking problems and sometimes shortening the useful life of a satellite. For example, in May 1998 loss of telephone pager service to 45 million customers was caused by a solar storm. During the Gulf War in 1991 military forces reported high frequency radio communications interruptions due to ionization storms, and in January 1994 an extended period of high electron levels caused failure of two Canadian communications satellites, which interrupted telephone, television, and radio service for several hours.

Airline Industry

Airlines are concerned about space weather because it can disrupt satellite and ground-based communication systems, which allow air traffic controllers to talk directly to pilots. Federal regulations require airlines to maintain communication capability with their aircraft at all times. Additionally, navigation systems can be affected by space weather events. Finally, because of the curvature of the Earth, planes flying from North America to Asia generally make flights over the North Pole, where passengers can be susceptible to higher doses of solar radiation than traditional non-polar flights. United Airlines reports that for the 21-month period from January 2002 through September 2003 there were approximately 140 flights that were or could have been affected by space weather events.

Questions for Witnesses

Dr. Ernest Hildner, Director, Space Environment Center, National Oceanic and Atmospheric Administration (NOAA)

1. Please provide an overview of NOAA's Space Environment Center (SEC). What research programs are performed at the center? What operational services are provided by the center?
2. Please describe the different types of solar weather events and specifically explain the time it takes for them to travel to the Earth. What is the lead-time we currently have for reacting to or mitigating the effects of solar weather? Please provide historical examples of when space weather events have affected human activities.
3. Who are the users of SEC products and information?
4. Please describe the relationship between the SEC, NASA, and the Air Force Weather Agency, including a specific explanation of the role of each agency in understanding and predicting space weather.
5. If the FY04 final appropriation for the SEC was the $5.2 million recommended in the House bill, what would be the impact on SEC services?

Col. Charles L. Benson, Jr., Commander, Air Force Weather Agency

1. Please provide an overview of the Air Force Space Weather Services provided through the Air Force Weather Agency.
2. Please describe the relationship between NOAA's Space Environment Center (SEC), NASA, and the Air Force Weather Agency, including a specific explanation of the role of each agency in understanding and predicting space weather.
3. Who are the users of Air Force space weather products and information?
4. Are there any technical barriers to the Air Force Weather Agency taking on the duties of the SEC if it were no longer funded through NOAA? Given that the Air Force's capabilities are designed for military purposes, how would you have to adapt your practices to provide SEC-like services to the civilian sector?
5. What would be the impacts on the Air Force and overall military operations if SEC no longer existed? Please provide specific examples when possible.

Dr. John M. Grunsfeld, Chief Scientist, National Aeronautics and Space Administration (NASA)

1. Please provide an overview of how space weather can affect NASA operations, including examples of historical events that have caused problems.

2. How does NASA use data and products from NOAA's Space Environment Center (SEC)? In general, how much lead time do you need to make decisions for mitigating the effects of space weather?
3. How would you compare our knowledge today of the impacts of space weather on NASA operations to what we knew five years ago, and to what we expect to know five years from now?
4. What would be the impact to NASA if SEC were no longer able to provide its space weather forecasts to you? Please provide specific examples when possible.
5. Are there any technical barriers to NASA taking on the duties of the SEC if it were no longer funded through NOAA? Given that NASA's mission is research oriented, how would you have to adapt your practices to provide SEC operational services?

Mr. John Kappenman, Manager, Applied Power Systems, Metatech Corporation

1. Please provide an overview of how space weather can affect electric power grid systems, including examples of historical events that have caused problems.
2. How does your organization use data and products from NOAA's Space Environment Center (SEC)? In general, how much lead time do you need to make decisions for mitigating the effects of space weather?
3. How would you compare our knowledge today of the impacts of space weather on electric power grid systems to what we knew five years ago, and to what we expect to know five years from now?
4. What would be the impact to your organization and the electric power grid industry if SEC were no longer able to provide its space weather forecasts to you? Please provide specific examples when possible.

Captain Hank Krakowski, Vice President of Corporate Safety, Quality Assurance and Security, United Airlines

1. Please provide an overview of how space weather can affect airline operations, including examples of historical events that have caused problems.
2. How does your organization use data and products from NOAA's Space Environment Center (SEC)? In general, how much lead time do you need to make decisions for mitigating the effects of space weather?
3. How would you compare our knowledge today of the impacts of space weather on airline operations to what we knew five years ago, and to what we expect to know five years from now?
4. What would be the impact to your organization if SEC were no longer able to provide its space weather forecasts? Please provide specific examples when possible.

Dr. Robert Hedinger, Executive Vice President, Loral Skynet

1. Please provide an overview of how space weather can affect satellite operations, including examples of historical events that have caused problems.
2. How does your organization use data and products from NOAA's Space Environment Center (SEC)? In general, how much lead time do you need to make decisions for mitigating the effects of space weather?
3. How would you compare our knowledge today of the impacts of space weather on satellite operations to what we knew five years ago, and to what we expect to know five years from now?
4. What would be the impact to your organization if SEC were no longer able to provide its space weather forecasts? Please provide specific examples when possible.

Chairman EHLERS. This hearing will come to order. Good morning. Welcome to the oversight hearing entitled: "What Is Space Weather and Who Should Forecast It?" And if you don't know what it is, you can go out and look outside and you will get some idea of what space weather is. Well, I wanted to make it clear, since I have been asked this, that the solar storm that is currently underway did not start the fires in California.

As a physicist, I must admit that when we began to plan for this hearing last month, I did not think it would conjure much attention outside of the scientific community. However, thanks to Divine Intervention, we now have major solar storm activity to coincide with the hearing. We certainly hope that the lights will stay on and our webcast capabilities will not be diminished during the course of this hearing.

The purpose of the hearing is to examine the National Oceanic and Atmospheric Administration's, better known as NOAA, Space Environment Center. This center, abbreviated SEC, but not to be confused with buying and selling stocks, provides real-time monitoring and forecasting of solar storms. The SEC is located with other NOAA labs in Boulder, Colorado in the District of Mr. Udall, the Subcommittee Ranking Member sitting directly to my right.

Many of us may think of solar eruptions as a curiosity or as the source of the beautiful *Aurora Borealis* often observed by residents in the northern U.S. However, as highlighted by recent media attention, these solar events can have serious repercussions for Earth-based technological systems. They cause geomagnetic storms in the Earth's atmosphere that can disrupt communication systems, cause surges on electric power grids, and be harmful to airline passengers and astronauts. NOAA's SEC provides vital space weather forecasts for civilian industries concerned with these effects. Additionally, SEC forecasts are used by the Air Force to provide tailored recommendations for military users concerned with space weather. For example, I believe the current space storm was predicted a good two days before it began.

Despite its important role in protecting the Nation's technological systems from geomagnetic storms, some here in Congress have proposed to reduce or eliminate funding for NOAA's SEC. In the House fiscal year 2004 appropriations bill for NOAA, SEC funding levels are 35 percent below the Administration's request of $8 million. Of even greater concern, the Senate Appropriations Committee bill contains no funding for SEC and includes the suggestion, without any justification, that the Air Force or the National Aeronautics and Space Administration, better known as NASA, should take on the duties of predicting space weather.

Today, we will hear from representatives of NOAA, the Air Force, and NASA about the roles of each agency in monitoring and forecasting space weather. Then we will hear from representatives of three industries that rely on SEC forecasts: the electric power grid industry, the airline industry, and the communications satellite industry. These experts will help us to better understand the impact of space weather on the Earth and its surroundings and to examine the question of who should be responsible for forecasting it.

Before we hear from our Ranking Member and our witnesses, I wanted to show a short movie clip of the most recent solar flare to set the mood for today's hearing. So we will now show that. I am not quite sure how that is going to show up in the transcript of the hearing, but we will take a quick look.

[Video]

Chairman EHLERS. Thank you very much. If I might mention yesterday, just out of curiosity, I went to the site, the solar site, and looked at one of the images. I took my little ruler and measured the diameter of the sun and the size of the flare compared to the sun. Then did a quick mental calculation. I can't guarantee this is accurate, and I probably shouldn't even say it, but my quick mental calculation indicated that the size of the flare, as apparent from that particular picture, was approximately 60 Earth diameters. That gives some startling idea of the scale of this. If the Earth had been there, it would have been an insignificant dot compared to the size of the flare. And that indicates the strength of the storms that we deal with.

Before I will recognize my Ranking Member, I also want to mention that we are going to have problems with the House schedule today. I understand that we are likely to have a vote in approximately 20 minutes, and unfortunately, we are very Pavlovian here; when the bells ring, we go vote. We will simply have to suspend the hearing while we go vote. We may well be interrupted by other votes later, but we will try to proceed as expeditiously as we can.

The Chair now recognizes Mark Udall, the Ranking Minority Member on the Environment, Technology, and Standards Subcommittee for his opening statement.

[The prepared statement of Chairman Ehlers follows:]

PREPARED STATEMENT OF CHAIRMAN VERNON J. EHLERS

Good morning! Welcome to this oversight hearing entitled, *"What Is Space Weather and Who Should Forecast It?"* As a physicist, I must admit that, when we began to plan for this hearing last month, I did not think it would garner much attention outside the scientific community. However, thanks to divine intervention, we now have major solar storm activity to coincide with the hearing. We hope the lights will stay on, and our webcast capabilities will not be impacted.

The purpose of the hearing is to examine the National Oceanic and Atmospheric Administration's (better known as NOAA) Space Environment Center. This center, abbreviated SEC, provides real-time monitoring and forecasting of solar storms. The SEC is located with other NOAA labs in Boulder, Colorado, in the district of Mr. Udall, the Subcommittee Ranking Member.

Many of us may think of solar eruptions as a curiosity, or as the source of the beautiful *Aurora Borealis* often observed by residents in the northern U.S. However, as highlighted by recent media attention, these solar events can have serious repercussions for Earth-based technological systems. They cause geomagnetic storms in the Earth's atmosphere that can disrupt communication systems, cause surges on electric power grids, and be harmful to airline passengers and astronauts. NOAA's SEC provides vital space weather forecasts for civilian industries concerned with these effects. Additionally, SEC forecasts are used by the Air Force to provide tailored recommendations for military users concerned with space weather.

Despite its important role in protecting the Nation's technological systems from geomagnetic storms, some here in Congress have proposed to reduce or eliminate funding for NOAA's SEC. In the House Fiscal Year 2004 appropriations bill for NOAA, SEC funding levels are 35 percent below the Administration's request of eight million dollars. Of even greater concern, the Senate Appropriations Committee bill contains no funding for SEC and includes the suggestion, without any justification, that the Air Force or NASA should take on the duties of predicting space weather.

Today we will hear from representatives of NOAA, the Air Force and NASA about the roles of each agency in monitoring and forecasting space weather. Then we will hear from representatives of three industries that rely on SEC forecasts—the electric power grid industry, the airline industry, and the communications satellite industry. These experts will help us to better understand the impact of space weather on the Earth and to examine the question of who should be responsible for forecasting it.

Mr. UDALL. Thank you, Mr. Chairman. Good morning to the panel and all of you who have assembled here to attend this important hearing. I want to begin by thanking the Chairman for holding this hearing. And of course, I have to thank him, also, for his impeccable timing. He managed to arrange for the sun spot activity last week to occur and then the solar flare this week has really given us a firsthand understanding of the importance of space weather and the need for the space weather forecasting services provided by NOAA's Space Environment Center, the SEC. And I would think, Mr. Chairman, this SEC is at least as important as the other SEC, particularly over the long-term as we have learned more about space weather.

Sunspots, geomagnetic storms, and solar flares, the phenomena of space weather, used to be a topic solely in the province of space scientists. While we have experienced the effects of these phenomena in the past, we had no ability to monitor or forecast these storms or to anticipate their likely effects. Some of you here know about the large solar flare that was generated in 1859, September of 1859, which shorted out telegraph wires in the U.S. and in Europe. And caused numerous fires.

Today, because of the importance of communications, electricity, and transportation to our daily lives, a similar storm would have devastating impacts in the absence of space weather forecasting. Satellites, transformers and transmission lines, and the billion dollar infrastructure that supports these essential services, are all vulnerable to space weather events. The SEC's forecasts enable government and private sector operators to take actions to minimize disruptions in service and damage to critical infrastructure.

The SEC's annual budget, really of a mere $8 million, seems modest when we evaluate it in the context of the Nation's investment in space weather monitoring and research and in comparison to the billions of dollars of infrastructure and services that are vulnerable to space weather events.

After investing millions of dollars and many years of research on space weather, we are now able to monitor solar storms and forecast their nature and intensity. Eliminating the SEC or drastically cutting its budget does not save money; it actually wastes taxpayer investments in research by cutting off the service that is currently delivering real benefits. Cutting the SEC's budget reverses, in my opinion, and I believe the opinion of many people here and people around the country, our progress in space weather forecasting, putting billions of dollars of infrastructure and services at risk.

This committee, in my opinion, should endorse the Administration's fiscal year 2004 budget request enthusiastically for those reasons. We should also continue to support research to improve space weather forecasting and to expand our knowledge of space weather and its potential impacts.

While the space weather forecasting discipline is still in its infancy, we still—it is no less essential than terrestrial weather forecasting. If we do not continue to invest in space weather forecasting, we will not only enjoy gazing at the Northern Lights, but we will risk experiencing widespread blackouts. Let us keep the lights on, the planes flying, and the communications flowing by fully investing in the Space Environment Center and its vital research and forecasting activities.

Mr. Chairman, I am also aware of a number of people with interests in space weather who wish to contribute to the record for this hearing. Therefore, I would ask unanimous consent that the record for this hearing be open—held open for 10 days to enable trade groups, private citizens, academics, and industry representatives to submit material to the record.

Chairman EHLERS. So ordered.

Mr. UDALL. Thank you, Mr. Chairman.

In conclusion, the witnesses we have here today will help us to better understand the phenomena and potential impacts of space weather events on our government activities and on our economy. We have an excellent panel of witnesses for our hearing today. I want to thank you all for taking your time to appear before the Subcommittee this morning, and I do look forward to your testimony.

With that, Mr. Chairman, I would yield back any time I have remaining.

[The prepared statement of Mr. Udall follows:]

PREPARED STATEMENT OF REPRESENTATIVE MARK UDALL

Good morning.

First, I would like to express my thanks to the Chairman for holding this hearing and to congratulate him on his timing. I don't know how you managed to arrange for the sun spot activity last week, Mr. Chairman, but the solar flare that reached Earth this past week illustrates the importance of space weather and the need for the space weather forecasting services provided by NOAA's Space Environment Center (SEC).

Sun spots, geomagnetic storms, and solar flares—the phenomena of space weather—used to be a topic solely in the province of space scientists. While we have experienced the effects of these phenomena in the past, we had no ability to monitor or forecast these storms or to anticipate their likely effects. For example, a large solar flare generated in September of 1859 shorted out telegraph wires in the U.S. and in Europe causing numerous fires.

Today, because of the importance of communications, electricity, and transportation to our daily lives, a similar storm would have devastating impacts in the absence of space weather forecasting. Satellites, transformers, and transmission lines—and the billion dollar infrastructure that supports these essential services are all vulnerable to space weather events. The SEC's forecasts enable government and private sector operators to take actions to minimize disruptions in service and damage to critical infrastructure.

The SEC's annual budget of $8 million seems modest when we evaluate it in the context of the Nation's investment in space weather monitoring and research and in comparison to the billions of dollars of infrastructure and services that are vulnerable to space weather events.

After investing millions of dollars and many years of research on space weather, we are now able to monitor solar storms and forecast their nature and intensity. Eliminating the SEC or drastically cutting its budget does not save money. It wastes taxpayer investments in research by cutting off the service that is currently delivering real benefits. Cutting the SEC's budget reverses our progress in space weather forecasting, putting billions of dollars of infrastructure and services at risk.

This Committee should endorse the Administration's FY04 budget request, enthusiastically. We should continue to support research to improve space weather forecasting and to expand our knowledge of space weather and its potential impacts.

While space weather forecasting is still in its infancy, it is no less essential than terrestrial weather forecasting. If we do not continue to invest in space weather forecasting, we will not only enjoy gazing at the Northern lights, but we will also risk experiencing widespread blackouts. Let's keep the lights on, the planes flying and communications flowing by fully funding the Space Environment Center and its vital research and forecasting activities.

Mr. Chairman, I am also aware of a number of people with interests in space weather who wish to contribute to the record for this hearing. Therefore, I ask unanimous consent that the record for this hearing be held open for ten days to enable trade groups, private citizens, academics and industry representatives to submit material to the record.

The witnesses we have here today will help us to better understand the phenomena and potential impacts of space weather events on our governmental activities and on our economy. We have an excellent panel of witnesses for our hearing today. I thank you all for appearing before the Subcommittee this morning and I look forward to your testimony.

Chairman EHLERS. All right. If there is no objection, all additional opening statements submitted by the Subcommittee Members will be added to the record. Without objection, so ordered.

At this time, I would like to introduce our witnesses. We will begin with a special introduction by our Ranking Member, Mr. Udall.

Mr. UDALL. Thank you, Mr. Chairman.

I want to take this time to acknowledge Dr. Hildner, who is here from my hometown of Boulder. Dr. Hildner is the Director of NOAA's Space Environment Center, the SEC, we have been mentioning. It is located in Boulder, as I mentioned. Dr. Hildner is a solar physicist who has worked for the High Altitude Observatory at NCAR, which is also based in Colorado, and at NASA's Marshall Space Flight Center in Alabama where he was the head of its Solar Physics Branch. He was an experimental scientist for Skylab and the Solar Maximum Mission during the 1970's. Dr. Hildner's scientific specialty is coronal and interplanetary physics about which he has published dozens of papers. Last year, the National Academy of Sciences called the work of the SEC "crucial." Under Dr. Hildner's steady watch, the Center continues to do its crucial work very well, though recent budget cuts have made his job, and the jobs of NOAA's SEC staff more difficult.

I look forward to hearing from Dr. Hildner today as he helps us understand the importance of the Space Environment Center.

Welcome, Dr. Hildner.

Chairman EHLERS. And with that background, he can tell me later whether my mental calculation was correct.

Next, it is my pleasure to introduce Colonel Charles L. Benson, Junior. He is the Commander of the Air Force Weather Agency at Offutt Air Force Base in Nebraska. Following him is Dr. John M. Grunsfeld, Chief Scientist of the National Aeronautics and Space Administration, better known, of course, by its acronym, NASA. The next witness to be introduced by the honorable gentleman from Minnesota, Mr. Gutknecht.

Mr. GUTKNECHT. Well, thank you, Chairman Ehlers.

And I just want to welcome the panel. And Chairman Ehlers and I have had the opportunity to go out and visit the NOAA center out in Boulder, and we were duly impressed with the work that is done.

But it is my honor today to introduce John Kappenman from Metatech Corporation in Duluth, Minnesota. For those of you who

have never had the chance to go to Duluth, Minnesota, it is one of the most beautiful cities, not only in Minnesota, but, I think, in the country. And if you don't get a chance to go to Duluth and visit the city, or go fishing in the beautiful waters of Lake Superior, at least you can go to my website and you can see a very large lake trout, which I caught there about two months ago. And I am very proud of that picture. And it is on the front page of my website.

For the past 27 years, Mr. Kappenman has researched electronic power system impacts caused by widespread geomagnetic field disturbances due to space weather. Since 1997, he has been employed with Metatech Corporation where he has advised folks worldwide on how to protect technology and power grid systems.

We all look forward to your testimony, and we welcome you here to Washington.

Chairman EHLERS. Thank you, Mr. Gutknecht.

I now understand the reason for the low lake levels in the Great Lake system: you are taking all of the fish out of them.

Next, it is my pleasure to introduce Captain Hank Krakowski. He is the Vice President of Corporate Safety, Quality Assurance, and Security for United Airlines located in Chicago, Illinois. And our final witness is Dr. Robert Hedinger. He is the Executive Vice President of Loral Skynet out of Bedminster, New Jersey.

As our witnesses should know, I presume you have been briefed, testimony is limited to five minutes each, particularly with a large panel like this, so we ask that you honor that request. And the little device here will show green for the first four minutes, yellow for the next minute, and then it turns red and all sorts of bad things happen. So we request that you try to keep it to five minutes each.

We will start with Dr. Hildner.

STATEMENT OF DR. ERNEST HILDNER, DIRECTOR, SPACE ENVIRONMENT CENTER, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dr. HILDNER. Good morning, Chairman Ehlers and Members of the Subcommittee. And thank you, Mr. Udall, for your kind introduction. As Director of the National Oceanic and Atmospheric Administration Space Environment Center, I am pleased to join these other witnesses and you today for the hearing on SEC's role in providing operational space weather information to the United States. We believe that NOAA is the proper home for the Nation's space weather service.

The extensive media coverage of recent radiation and geomagnetic storms clearly illustrates the Nation's need for accurate, reliable, and timely space weather forecasting. The effects of space weather, as you have already indicated, are far ranging. We know that airlines, the International Space Station, nuclear power plants, and at least one satellite were affected by the recent solar and space weather events. NOAA's SEC is the central focus of information for these kinds of events.

[Slide]

The next figure shows that—sorry. I am in control here, I think.

The next figure in the upper left shows the number of web accesses to our site. And that spike, over the last several days,

reaches almost ten million hits on our website per day. Even before the recent activity and the media attention, customers hit our website over 500,000 times a day, and that is that lower part on the left. This figure also shows several of the NOAA products used by radio communicators, by airlines, by satellite operators, and the various alerts and warning products issued by SEC in the last week in the upper right. That figure, which is too small to see, actually tells you how many times we sent out alerts and warnings to our customers for our various products.

The recent media coverage of effects show there is a direct correlation between space weather and the U.S. economy. The direct global economic impact of space weather has been estimated very conservatively at $200 million per year. It is clear that the adverse conditions in the space environment can disrupt communications, navigation, air travel, national electric power distribution grids, and satellite operations. Improved space weather information will assure safety, reliability, and national security, as my colleagues today will discuss the benefits of space weather forecasting for their work.

However, I would like to highlight some important points about SEC, and one of those is the funding issue that has already been eluded to. I would be remiss if I didn't ask for your assistance. As you stated, the President's budget recommends $8.3 million for SEC in fiscal year 2004. The House Appropriations Committee has recommended $5.3 million, fully $3 million below the President's request, and the Senate Appropriations Committee has zeroed out funding entirely.

If either level below the President's request is enacted, there will be dramatic consequences for SEC and for the vital services that it provides. In response to the necessary staff reductions, NOAA will be faced with the choice of eliminating SEC's research and development activities or its services. If the R&D is cut, NOAA will not be able to improve products, models, and data streams needed by our customers. On the other hand, cutting services means that our customers will only receive data: no value added forecasts, no warnings, no alerts. Either choice means our effectiveness as a partner to other government agencies, such as NASA and the Air Force, will drop.

I need to emphasize that zeroing out SEC's budget will eliminate the one source of official U.S. space weather alerts, warnings, and forecasts. Space weather is defined by the National Space Weather Program as: "Conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health."

SEC monitors, predicts, and forecasts conditions in the space environment and provides critical data, space weather data, to a variety of government and commercial customers. SEC also conducts research into phenomena affecting the space environment.

[Slide]

As the next figure indicates, space weather begins to—space weather begins at the sun, and this animation shows the brightening of the sun, if you can run the movie, please——

[Video]

At the time of a flare, the spray of swift energetic particles and a cloud of solar atmosphere depart the sun. When it arrives at Earth, it causes a geomagnetic storm, much as what happened on Wednesday morning this week.

SEC provides services, conducts research and development, and builds and maintains the computer systems, which support the Center's work. SEC's efforts are focused on areas where advanced applications can be brought to bear. We continually monitor. We continually monitor Earth's space environment with displays and software driven by the approximately 1,400 data sets that we receive everyday. The forecasters synthesize current data, climatological statistics, and relevant research results to formulate our daily predictions of solar and geophysical activity.

The future of SEC's vital role in conducting and coordinating research in its applications was discussed, as mentioned earlier, in a recent National Research Council report, a Decadal Research Strategy in Solar and Space Physics. In this report, the NRC recommended that NOAA assume full responsibility for space-based solar wind measurements and it should expand its facilities for integrating data into space weather models.

It looks like my time is up, so let me, in conclusion, say that the Space Environment Center is the Nation's unique civilian provider of critical, real-time information and forecasts on space weather that affect the United States' economic, national, and homeland security. We want to remain in that role.

Thank you, Mr. Chairman and Members of the Subcommittee, for this opportunity to testify on this extremely important matter to NOAA and the Nation. And I would be happy to answer any questions.

[The prepared statement of Dr. Hildner follows:]

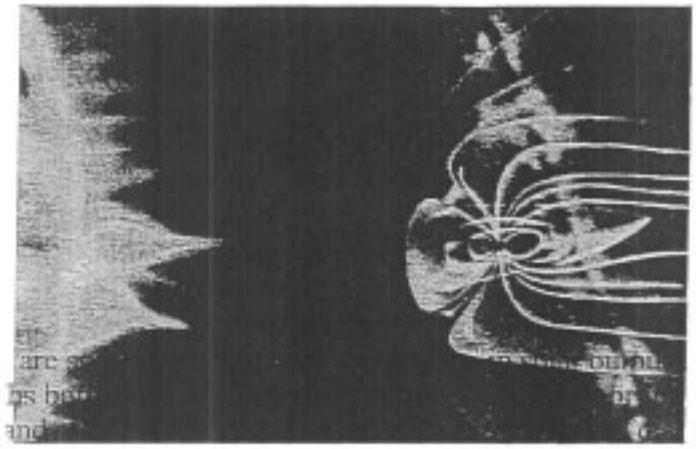
PREPARED STATEMENT OF ERNEST HILDNER

Thank you, Mr. Chairman and Members of the Subcommittee, for the opportunity to testify before you regarding the National Oceanic and Atmospheric Administration's (NOAA) activities at the Space Environment Center (SEC). I am Ernest Hildner, Director of the SEC and responsible for day-to-day management and long-term planning of the Center. Space, from the Sun to Earth's upper atmosphere, is a strategic and economic frontier. This unique environment influences a multitude of human activities, and its understanding presents numerous scientific challenges. NOAA's SEC has a central role in conducting and coordinating research to understand the space environment to improve space weather services, and in providing critical operational space weather services for NOAA and the Nation. SEC strives to understand and predict the state of the space environment by accumulating data, running models, applying forecaster insight, conducting applied research, and utilizing research and data obtained externally to make operational forecasts of the space environment. Today I will provide an overview of space weather, of SEC and the services it provides, the budgetary and science challenges facing SEC, how SEC collaborates with other agencies, and the value of space weather forecasting and research. I am pleased to have the chance to discuss these topics today.

SPACE WEATHER

> *"Space weather" refers to conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. Adverse conditions in the space environment can cause disruption of satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socio-economic losses.* National Space Weather Program Strategic Plan, FCM–P30–1995.

The Earth lies 150 million kilometers, or 93 million miles, from the Sun, but it is immersed in the extended solar atmosphere. Our magnetic field resists the continual outflow of ionized gas from the Sun, protecting us here at the surface. However, the Earth and its field represent an obstacle to the solar outflow. As a result, the geomagnetic field is compressed on the sunward side of Earth and drawn out away from the Sun to make a comet-shaped cavity. As shown in the artist's sketch below, the size of the boundary between Earth's dominion and the Sun's varies with the pressure exerted by the Sun's outflow.

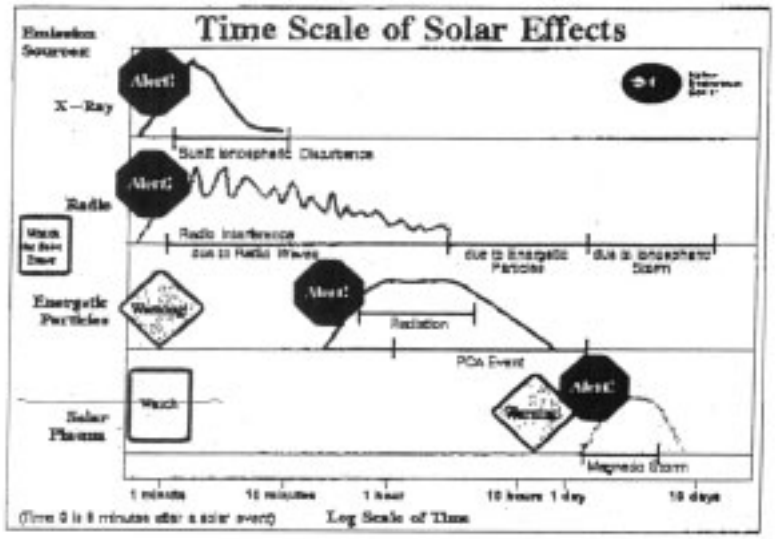


Space weather storms are spawned by a variety of changes in solar outputs. First, the light from the Sun, at wavelengths both longer and shorter than the visible, can brighten abruptly. This light travels to Earth and affects the near-Earth environment just as we discern that a solar event has occurred. The photons from a solar flare produce a radio blackout, at some frequencies, by changing the character of the dayside ionosphere and upsetting the delicate balance between the Sun's otherwise nearly constant output and Earth's ability to receive and ingest it.

Solar energetic particles comprise a second type of solar emission. These particles, predominantly protons, the nuclei of hydrogen atoms, are accelerated in coronal mass ejections and solar flares. They travel from the Sun slower than the speed of light, arriving near Earth as soon as tens of minutes after the solar eruption, the more energetic particles usually arriving first. The transit from sun to Earth may be slowed if the intervening magnetic fields do not provide easy Sun-to-Earth connection; then the particles' arrival may be delayed many tens of hours. A major rise in energetic particle flux is commonly referred to as a radiation storm.

A third type of solar emission that has strong space weather impacts is magnetized plasma. When the continually evolving solar magnetic fields abruptly restructure themselves over a broad area, a portion of the outer solar atmosphere, the corona, can be ejected violently into space. These coronal mass ejections, clouds of ionized gas (solar plasma) and their embedded magnetic fields, fly away from the Sun at 400–1000 kilometers/second (1–2 million miles per hour). If Earth happens to be in the way, when the cloud strikes Earth's magnetic field 2 to 4 days later, then our geomagnetic field is compressed and may be eroded, resulting in a geomagnetic storm.

The following diagram depicts the times scales associated with these three types of space weather events.



The diagram illustrates the lead time between the occurrence of the parent event at the Sun and the terrestrial response; as well as the watches, warnings, and alerts issued by SEC. Thus, space weather has several kinds of storms much as meteorological weather has storms as different as tornadoes, blizzards, and hurricanes. A particular type of space weather storm has significant impacts on particular technologies so some customers are impacted by one type of space weather storm but not by another.

For example, strong x-ray bursts have a serious impact on high frequency (HF) communications on the dayside of Earth. ARINC, a provider of air traffic communications capabilities to commercial airline flights over the North Atlantic, ensures the safety of the movements of airplanes in flight with communications to the cockpit. They need to know when the HF communications are being affected due to natural conditions (space weather) or due to some equipment failure, and advise aircraft of appropriate frequencies to use. The United States Coast Guard is alerted by SEC staff during these same types of episodes as its LORAN navigation system will be unable to provide the required accuracy to its users during solar flare events. LORAN is intentionally made unavailable during these disturbed space weather conditions.

During bursts of solar energetic particles, the second type of space weather storm, the potential for biological damage due to elevated solar radiation increases. The NASA Space Radiation Analysis Group is responsible for assuring that humans in space not receive anything beyond the lowest reasonable radiation dose. They will advise the Flight Surgeon at NASA's Johnson Space Center to alter the activity plan for the crew if those activities involve leaving the space craft (for an extra-vehicular activity, or EVA), or suggest moving the crew to the most highly protected area of the Space Shuttle or International Space Station during the space weather radiation storm. NASA requires forecasts and specifications of radiation that affects both humans and equipment in space.

Another witness will discuss the effects of radiation storms and communications degradation on the airline industry.

Satellites in orbit and during the launch are at risk from radiation storms, and I am pleased to see that you have a witness to discuss those effects of space weather as well.

The third type of space weather storm, caused by the interaction between the onrushing magnetized plasma from the Sun and Earth's own magnetic field, is particularly menacing. This geomagnetic storm can be thought of as the space weather version of a strong hurricane, as it has very widespread impacts across a large number of systems and users. Somewhat like hurricane clouds are monitored from sat-

ellites, this plasma cloud can be seen as it leaves the Sun and it is probed internally as it is about to make "Earthfall."

When a coronal mass ejection occurs, forecasters at SEC analyze the direction of the ejectum to determine whether it is Earth-bound and estimate the kinetic energy associated with the event. As it takes a few days for the cloud to reach Earth, there is time for users to take preventive or mitigating action. One of today's witnesses will discuss the effects of geomagnetic storms on the electric power grid.

SEC has been called upon to help investigate possible environmental causes for disasters. The recently active Shuttle Columbia Accident Investigation Board asked for testimony to rule out the possibility that a radiation storm could have affected the Shuttle's computers during reentry. More recently, there were inquiries whether the electrical blackout of the Northeast on August 14, 2003, was caused by a space weather geomagnetic storm. SEC saw no evidence that it was. Ironically, however, as the grid was being brought back up to capacity, on August 18 there was a strong geomagnetic storm that hampered the ability of the operators to return to normalcy.

Another system impacted during geomagnetic storms is the Wide Area Augmentation System (WAAS) of the Federal Aviation Administration, designed for aircraft navigation en route. The WAAS technology relies on the use of the Global Positioning System (GPS), and GPS accuracy is adversely affected during geomagnetic storms. In the current solar cycle, the space weather storm of July 14–15, 2000, was by many measures the most serious. During this storm, the "Test-bed" WAAS was unable to determine the position of a receiver on an airplane to the accuracy required; as a result of the storm, slight changes were made to the WAAS model based on data received during that solar activity.

The Space Weather Operations group at SEC issues alerts, warnings, and watches of space weather storms, on a 24/7 basis. Warnings of all three types of space weather storms are issued when there is high probability of occurrence. Warnings for radiation and magnetic storms are aided by the ability to detect the incoming solar wind from a satellite one million miles upstream, the Advanced Composition Explorer (ACE). This sentinel allows for a few minutes advance notice of radiation storms, and up to one hour lead time for magnetic storms. However, it does not offer any benefit for radio blackouts.

Space weather events such as radio blackouts, radiation storms, and geomagnetic have affected various technologies and systems in sometimes spectacular ways. During the last solar cycle, a geomagnetic storm caused the Hydro-Quebec power grid to black out on March 13, 1989, leaving six million without electricity for nine hours. The big storms of March 1989 and July 2000 sent engineers back to their drawing boards hoping to design better systems to lessen the damage. A space weather radiation storm in August 1972 could have been even more damaging, possibly lethal. This event occurred between the lunar flights of Apollo 16 (April 16, 1972) and Apollo 17 (December 16, 1972). Biologists have calculated that the radiation received by astronauts, had they been on the moon at the time of the storm, would have caused a quick death. Good luck averted a disaster.

The frequency of occurrence of space weather storms, and the possible consequences of the storms, are indicated in the NOAA Space Weather Scales document attached to this testimony and available on SEC's website at http://www.sec.noaa.gov.

SEC OVERVIEW

What we now call "space weather" began to affect widely used technology during World War II, disrupting the newly developed communication and radar systems. After the War, the Central Radio Propagation Laboratory was set up in the National Bureau of Standards in Boulder, Colorado, coalescing federal activities dealing with space weather. A portion of this unit, by then named the Environmental and Solar Data Service, was folded into the Environmental Science Services Agency (ESSA) when it was formed in the 1960s. Daily forecasting of the space environment for the public commenced in 1965. ESSA was rolled into NOAA when NOAA was formed in 1970, and the SEC is the result.

NOAA's mission *"To understand and predict changes in the Earth's environment. . .to meet our nation's economic, social, and environmental needs"* includes space weather. Just as NOAA's tropospheric weather service does for its customers, NOAA's space weather service monitors and predicts conditions in the space environment for its customers. SEC carries out its role as the Nation's official source of space weather alerts and warnings under various legislative mandates, statutory authorities, and Department of Commerce Reorganization Plans that gave the authority to monitor and predict the space environment to NOAA. Currently, SEC is both a research laboratory in NOAA's Office of Oceanic and Atmospheric Research (OAR) and one of the National Weather Service's (NWS) National Centers for Envi-

ronmental Prediction. SEC's products are distributed via e-mail, its Web site, the NWS Family of Services, time and frequency standards radio stations WWV and WWVH, and the NOAA Weather Wire; pager service to notify customers when SEC issues an alert is available from a commercial provider.

SEC is also a member of the International Space Environment Service (ISES), which has 12 Regional Warning Centers around the world to take observations and provide services of regional interest. Daily, the regional centers share their data and tentative predictions with SEC, which synthesizes the information and, as the World Warning Agency, issues the global forecast of space weather conditions. ISES traces its parentage to the International Council of Scientific Unions; its Regional Warning Centers are funded by their host countries.

NOAA's space weather service is analogous to its tropospheric weather service, and both antedate the formation of NOAA itself. Both serve civilian government, public, and industrial users, and both have links to military and academic partners. For both services, NOAA was deemed to be the proper home. Using NOAA's and others' sensors, the SEC continually monitors and daily forecasts Earth's space environment and provides accurate, reliable, and useful solar-terrestrial information to their customers. SEC acquires, interprets, synthesizes, and disseminates monitoring information to serve the Nation's need to reduce adverse effects of solar-terrestrial disturbances on human activities. It prepares and disseminates forecasts and alerts of conditions in the space environment. SEC conducts research into phenomena affecting the Sun-Earth environment including the emission of electromagnetic radiation and particles from the Sun, the transmission of solar energy to Earth via solar wind, and the interactions between the solar wind and Earth's magnetic field, ionosphere, and atmosphere. It conducts research and development in solar-terrestrial physics and in techniques to improve monitoring and forecasting, prepares high-quality data for national archives, and uses its expertise to advise and educate those affected by variations in the space environment. When events warrant, watches, warnings, and alerts are issued for the use of operators whose systems may be adversely affected by space weather storms. These user groups are private, commercial, government, and military operators, concerned with electric power distribution, high-frequency radio communications, satellite operations, astronaut protection, radio navigation, and national security.

The SEC, however, faces a number of challenges to meeting the needs of the user groups mentioned above. These challenges include budgetary challenges, particularly the potential of cuts in the President's budget request for SEC in the FY 2004 appropriations bills; and, scientific challenges.

The President requested $8.291 million total for the SEC in FY 2004. However, the House Appropriations Committee has recommended FY04 funding of $5.298 million for SEC, while the Senate Appropriations Committee zeroed out funding for SEC. If the House Committee level of $5.298 is enacted, there will be dramatic consequences for SEC and the vital services that it provides. The House mark of $5.298 million would support staffing of only about 25 FTEs, down from the 53 FTEs requested in the President's budget. In the short-term, most non-labor SEC costs are fixed.

Downsizing to the House Appropriation's Committee's recommended level, NOAA and SEC would attempt to preserve, as much as possible, the Nation's investment in the current space weather monitoring network by continuing to acquire, ingest, process, disseminate, and provide to archives the copious data with breaking the continuity of 30 years worth of measurements. This activity currently consumes about half of SEC's budget. Therefore, the shortfall created by an appropriation of $5.3 million would be borne either by research and development or by operations. NOAA and SEC will be forced to choose between the least undesirable of two options described below. In either case, SEC's data handling capability for ingest, processing, and archive would degrade. Eighty percent of Air Force alerts are driven by data provided only by SEC. The space weather data ingest and distribution network, identified by Homeland Security as a part of the Nation's Critical Infrastructure, would face imminent failure. For example, under each option, irreplaceable coverage gaps in real-time Solar Wind data would result, as satellite tracking shrinks, reducing alerts of geomagnetic storms affecting communications and GPS accuracy.

In the first reduction option, NOAA would eliminate SEC's research and development while continuing operational services with no improvement. Verification of and technique development to use Solar X-ray Imager (SXI) data would cease. When operational, the SXI takes images of the sun once a minute, providing additional data needed to more accurately forecast and alert users to space weather events. The Global Assimilation of Ionospheric Measurements (GAIM) model currently being developed would not become available to civilian users. This model will provide global specification and forecasts of the ionosphere in 3-dimensions, where pres-

ently only in-situ measurements and climatological models are available. NOAA participation in the National Space Weather Program will cease. SEC will not be able to provide improvements to products and models supporting airlines, power companies, navigation, and other critical services. NOAA will be unable to transition into operations the physics based models developed at national centers and universities by NSF, NASA, and DOD-supported scientists. In addition, SEC's website, the primary customer interface for the distribution of space weather data and information will not be improved and recovery from failure will be difficult.

In the second option, NOAA would eliminate SEC's operational space weather services while continuing research and development against the day that (improved) services can resume. NOAA would cease to issue official U.S. space weather alerts, warnings, and forecasts, information that is currently not provided by any other source. Unfortunately, reducing the current suite of products one-by-one saves very little until the last product is terminated. The infrastructure to support one product supports all, so there is little savings in reducing the number of products. Joint operations with the U.S. Air Force would stop, including providing back-up to the U.S. Air Force's classified space weather support to our armed services. Products supporting airlines, power companies, navigation, and other services and industries would not be prepared, issued, and updated. As noted for research and development, the SEC website would degrade and be prone to complete failure. Real-time operational data systems would be decommissioned.

SEC has several scientific challenges before it. An exciting effort is its work with academic and DOD partners to assimilate data into numerical models, similar to the significant assimilation challenge faced by the meteorological modeling community. The challenge combines computational science and physical understanding of the space environment and will lead to improvements in both. With successful "4–D data assimilation," the model outputs (space weather maps) will be more accurate and more skillful, therefore more useful to users of the services. SEC is working to ensure that space environment monitors designed for GOES and POES satellites provide useful and reliable data on every satellite. Researchers at SEC consult on and write requirements for space weather sensors and, when appropriate, on requirements for the satellites.

SEC has three Divisions; one for services; a second for research and development; and, a third to develop and maintain the computer systems which support the Center's work. The Research and Development Division derives its goals and targets from the needs of the Space Weather Operations Division. In turn, the space weather services products improve from the application of R&D. Having R&D and operational services in one Center encourages more frequent and more effective interaction and collaboration among the scientists, forecasters, and specialists at SEC. While forecasts, alerts, and warnings are routine for quiet and mildly unsettled solar conditions, when activity becomes intense, forecasters consult with the Center's research Ph.D.s about the forecast. This is because there are not yet good "rules of thumb" for how to deal with these situations, and the best expertise must be brought to bear on aspects of the problem. In addition, the pace of innovation and change is still very rapid in space weather, with researchers at SEC and elsewhere playing a major role in developing models that, if they could be transitioned swiftly into operations, would bring us progressively closer to the goal of physics-based, numerical space weather predictions.

The Research and Development Division is grounded in understanding the fundamental physical processes governing the regime from the solar surface, through the interplanetary medium, into the magnetospheric-ionospheric regions, and ending in Earth's upper atmosphere. These processes determine the climatology and nature of disturbances in the solar atmosphere, in Earth's magnetic field, in the ionosphere, in the charged particle populations at satellite orbits, and in the atmospheric density at high altitudes (including low-Earth orbit). SEC's research, technique development and new sensor implementation are focused on areas where advanced applications can be brought to bear to improve space weather services. The staff has expertise spanning from solar physics to Earth's upper atmosphere and maintains close collaborations throughout the larger research community. They publish regularly in scientific journals, and work directly with the SEC Space Weather Operations and the Systems Division to develop state-of-the-art capabilities for the SEC forecast center. The group develops analysis tools for working with data from a variety of spacecraft, including the NOAA geosynchronous and polar orbiters, and spacecraft in the solar wind. Data access is provided through customized data-analysis routines and individualized displays. In addition to enhancing the utility and value of the primary data through research and analysis, the group explores sources of new data and improved monitoring to support Space Weather Operations. The group

leads in the development of techniques to process and interpret both ground-based and space-based solar imagery, and has special expertise in solar X-ray imaging.

The Space Weather Operations Division is the Nation's official source of space weather alerts and warnings. The services center is staffed 24/7 with an operations specialist and, for ten hours a day, a forecaster They continually monitor Earth's space environment with displays and software driven by the approximately 1400 data streams received each day. Forecasters synthesize current data, climatological statistics, and relevant research results to formulate their daily predictions of solar and geophysical activity. Operations specialists ensure data integrity and timeliness; verify event validity and issue Alerts, Watches, and Warnings; and update announcements on the Geophysical Alert Broadcasts over radio station WWV and WWVH.

The Systems Division is responsible for: IT system architecture; computer security; developing or acquiring, and maintaining, the computer hardware and software to routinely ingest data; populating the data bases; the hardware and software for disseminating data and products to customers and to the archive; and providing computer configuration control and redundancy for operational reliability. In addition, Systems Division personnel provide system administration and support to internal users, while responding to IT directives from the NOAA and OAR Chief Information Officers, and working with administrators of the several local Internet services. The Division operates the receiving antennas at the prime and back-up Boulder sites, and has personnel on-call at all times to attend to hardware and software failures which affect the functions of the forecast center.

SEC performs a vital role for the Nation in conducting and coordinating research and its application. The recent National Research Council report—A Decadal Research Strategy in Solar and Space Physics (2003), recommended that NOAA should assume full responsibility for space-based solar wind measurements, expand its facilities for integrating data into space weather models, and, with NASA, should plan to transition research instrumentation into operations. As discussed in the National Space Weather Program Implementation Plan (2000), interagency programs cannot succeed in meeting the Nation's needs without NOAA SEC observations, research, model development, and transition to operations. And, as emphasized in the Department of Defense's (DOD) National Security Space Architect Study (2000), NOAA's current and planned activities are essential to meet DOD's space weather needs.

In addition to the SEC's activities, it should be noted that three line organizations play roles in the NOAA Space Weather Program: National Environmental Satellite, Data, and Information Service (NESDIS), National Weather Service (NWS), and Office of Oceanic and Atmospheric Research (OAR), with some interest and support from the National Ocean Service. They cover the gamut of space weather activities from setting requirements for future space environment monitoring sensors and spacecraft, to monitoring the development of the sensors for flight on the Geostationary Operational Environmental Satellites (GOES) or Polar Operational Environmental Satellites (POES), to tracking and downloading data from NOAA and non-NOAA satellites, to processing and distributing the data, and finally to archiving the data. Many of these activities are contained within and are an integral part of NOAA's major programs, such as the GOES and POES programs, so that only the Space Environment Center (OAR) and part of the National Geophysical Data Center (NGDC) in NESDIS are clearly identified budget structures tied directly to NOAA's space weather program. The requirements process also identifies observations needed in addition to the GOES and POES programs and programmatic plans are made for these platforms as well. NGDC is the sole archive of routine monitoring data of the space environment recorded on GOES, on POES, and on DOD's Defense Meteorological Satellite Program satellites. It is also the sole archive of space environment monitoring data recorded at DOD ground-based solar and ionospheric stations. As noted below, NOAA also works closely with other federal agencies and nations to obtain available real-time space weather data enabling more accurate and timely space weather services for the Nation.

COLLABORATION WITH PARTNERS

SEC works with a variety of partners to accomplish its mission. Internally, cooperative ventures abound as graduate students, post-doctoral students, visiting scientists, Cooperative Institute fellows from the University of Colorado, and contractors all contribute to the effort at the Center. Additionally, SEC works with the Cooperative Institute for Research in Environmental Sciences, a NOAA Joint Institute.

SEC works closely with colleagues across government agencies and academia, in the U.S. and internationally, to understand the space environment and apply research results. Collaboration requires a great deal of coordination within the U.S. and internationally. Within the U.S. Government, the Office of the Federal Coordi-

nator for Meteorology provides a mechanism for space weather coordination, including development and implementation of the National Space Weather Program (NWSP). The National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the Departments of Defense (DOD), Interior (DOI), Energy (DOE), Commerce (DOC), and Transportation (DOT) are participants in the NWSP, which recognizes common interests in space weather observing and forecasting. Aware of the need for prudent employment of available resources and the avoidance of duplication in providing these services and support for agency mission responsibilities, the cooperating departments have sought to satisfy the need for a common service and research program under the NWSP. The NWSP's Implementation Plan sets out the expected data, research, and services contribution from each participating agency.

To provide its specification and forecast services, SEC works most closely with the U.S. Air Force Weather Agency's forecast center in Omaha, which provides services to U.S. military customers. NOAA civilians and uniformed NOAA Corps and U.S. Air Force personnel together staff the joint services center in Boulder. NOAA and USAF share their data without charge to each other, and confer every day before the daily forecasts are issued by the two agencies to their respective clients. The SEC provides centralized space weather support to non-DOD government users, such as NASA, and to the general public, such as the commercial airline industry. SEC operates and maintains a national real-time space weather database to accept and integrate observational data, to provide operational support and services in the space and geophysical environment, to provide services to public users in support of the national economy, and to serve as the U.S. Government focal point for international data exchange programs. The USAF provides unique and classified support to all DOD users. The Space Weather Operations Center (SPACEWOC) at the Air Force Weather Agency (AFWA) serves as the DOD focal point for space weather forecasting support and services. The USAF maintains a worldwide network of both ground-based and space-based observing networks to provide accurate, reliable, and timely support to military communications, surveillance, and warning systems. To avoid duplication, the two agencies share responsibilities to produce certain space weather databases, warning, and forecast products of mutual interest and benefit to each other. AFWA and SEC provide cooperative support and backup for each other in accordance with existing agreements.

NOAA procures, operates, and maintains the Space Environment Laboratory Data Acquisition System (SELDADS) as the national system for collection, integration, and distribution of solar-geophysical data received in real-time from ground-based observatories and satellite sensors. Collection, processing, monitoring, and storage of the data occurs continuously around the clock. Displays and interactive analyses of the data are used by SEC to provide alerts, forecasts, and data summaries to a user community consisting of industrial and research organizations and Government agencies in the United States and abroad.

The collaboration among space weather service providers and those who fund their research is closely coordinated and mutually beneficial. NASA and DOD conduct critical research and development activities that NOAA assesses and incorporates, as needed, onto its civil operations spacecraft. NASA's upcoming Living with a Star set of missions and their accompanying data and research are oriented toward improving space weather monitoring and improving techniques for understanding space weather effects and the inference of the physical processes that shape the space weather environment. These are important because they enable the production of new physical models for improved predictability of the space weather environment and its evolution. The space industry also provides expertise to assist in various projects. Increasingly, collaborations with the private sector and foreign remote sensing operators provide data and information that NOAA and other government agencies such as the USDA, DOE, and DOI use to implement their respective missions.

SEC also works actively with partners in industry and other users on specific projects to identify research and forecast needs. For example, SEC has one active Cooperative Research and Development Agreement with Federal Data Corporation (FDC) to develop a model of the wavelength-dependent changing solar brightness for customers interested in ionospheric changes and heating of the terrestrial atmosphere. NASA's Marshall Space Flight Center (MSFC) and SEC scientists, with others, issue and update the world consensus forecasts of the 11-year cycle of solar activity for the benefit of NOAA, NASA, DOD, and others; this is the forecast used by NOAA, NASA, DOD, and the international community for mission planning. Spaceweather.com, a website fostered and supported by MSFC, makes heavy use of SEC's data and products. The website exhibits data gathered from SEC. SEC is first in the site's list of "essential" links.

SEC also co-sponsors Space Weather Week annually with other government agencies such as the Air Force Research Laboratory, NSF Division of Atmospheric Science, and NASA Sun-Earth Connection Program. This event brings hundreds of users, researchers, vendors, government agencies, and industry representatives together in a lively dialog about space weather. Discussion focuses on recent solar and geomagnetic activity, specific space weather impacts, and our scientific understanding of this activity. The conference program highlights space weather impacts in several areas of the environment including ionospheric disturbances, satellite drag, auroral currents, geomagnetic storms and their solar drivers, radiation belts, and solar energetic particles. The conference registration fee covers almost the entire cost of the conference. The rest of the conference expenses are covered by NSF, specifically some costs for invited speakers, students, special guests and support for international partners to attend. SEC, the DOD Air Force Research Lab and NASA all assist with the planning of Space Weather Week, and representatives from industries impacted by space weather including those from electric power, commercial airlines, satellite operations, and navigation/communications are among frequent participants and contributors. The attached spreadsheet highlights comments SEC has received from users about impacts of space weather on their efforts.

VALUE OF SPACE WEATHER FORECASTING AND RESEARCH

In the last few years, there has been a large increase in society's need for space weather information, as geomagnetic storms and solar disturbances can impact a wide array of sectors and industries ranging from transportation to electricity generation. SEC's website receives on average more than 500,000 hits per day from commercial and public users. This number can triple during severe space weather events. SEC forecasts and research helps support a wide array of needs including the U.S. power grid infrastructure, commercial airline industry, Global Positioning System or GPS, NASA human space flight activities, satellite launch and operations, and U.S. Air Force operational activities.

The direct global economic impact of space weather has been estimated at about $200 million per year. A one percent gain in continuity and availability of GPS information, which can be disrupted by space weather events, would be worth $180 million per year. DOD alone spends $500 million each year to mitigate space weather effects. In 1989, a space weather storm caused such significant orbital decays that the Air Force Space Command lost track of 1,300 of the 8,000 objects orbiting in space that it was tracking. In addition to the potential harm radiation from a space weather event can cause astronauts and sensitive electrical equipment in space, these rapid changes in flight paths of space debris could be potentially harmful should they intersect with the paths of astronauts or satellites in space. In March 1989, seven geostationary satellites had to make 177 orbital adjustments in two days, more than normally made in a year. Such wear reduces the satellites' useful lifespan. Destruction of AT&T's Telestar satellite by a severe weather event in 1997 disrupted TV networks and part of the U.S. earthquake monitoring network, and forced renegotiation of the sale of Telestar, resulting in a drop of $234 million in value. Submarine, continental cables, and parts of fiber optic cable systems have all been known to fail or be overloaded as a result of space weather.

Geomagnetically-induced currents can disrupt or wipe out electrical systems through power surges that cause network supply disruptions, transformer damage, and wear-and-tear on other components. As we apparently witnessed this summer during the blackout in the north, a single failure in the power grid can escalate into cascading damages and outages. Oak Ridge National Laboratory estimates that a blackout in the Northeast caused by geomagnetic storms could result in a $3–6 billion loss in Gross Domestic Product (GDP). A geomagnetic storm in 1989 caused $13.2 million in damage to power systems operators in Quebec, and another $27 million to power operators in New Jersey. In addition, the disruption creates additional impacts for power customers who lose electricity. After 1989, Hydro-Quebec spent $1.2 billion on capacitors to prevent potential space weather disruptions. A current, induced by severe space weather, in a liquefied gas pipeline that ignited when two trains passed over it is the suspected cause of an accident that killed over 500. Preventative measures, based on early forecasts from the SEC and its partners, can help mitigate the need for such costly alternatives as shielding power lines. One recent estimate suggested that the use of good forecasts by the power industry could save the U.S. $365 million per year, averaged over the solar cycle.

Not only do we depend more heavily on systems that can be adversely impacted by space weather, new systems and new modes of operation using old systems vulnerable to space weather have proliferated. Satellites are becoming smaller and cheaper because of reduced component size and increased computer speeds. Economic competition drives the need to reduce shielding and redundancy, but these

changes leave satellites more vulnerable to space weather disturbances. U.S. airlines are offering passengers the convenience of non-stop flights over the North Pole to Asian destinations; these flights (and research flights in Antarctica) sometimes experience air traffic control difficulties due to space weather. During a March 2001 space weather storm, 25 flights were rerouted to avoid the Poles because of the increased radiation risk.

National policy and defense planning have resulted in increased reliance on the use of commercial systems to gather information and move it between the United States and troops and ships in hot spots around the world. However, experiences during severe conditions of the last solar cycle indicates that some users may experience performance failures and degraded results during times of high solar and ionospheric activity. The nation is also placing large numbers of astronauts into radiation-vulnerable orbits for unprecedented periods of time during the assembly and operation of the International Space Station. Our increased need for improved space weather information to insure safety, reliability, and defense are inevitable outcomes of our growing use of space-weather-sensitive systems.

SEC has been keeping up with the changes, responding to new customer needs, research breakthroughs, and the changing face of space weather services. Among several successes, it has transitioned physics-based numerical models into the operational space weather service. It was possible to use the first of these university-developed models only when real-time solar wind data from upstream of Earth became available to drive them. Now forecasters get numerical guidance, much as meteorological forecasters do. Model output can be disseminated to provide customers with the space weather analogs of meteorological weather maps, showing event locations and intensities of computed fronts and boundaries. SEC has designed website to make it user-friendly for a range of audiences, from electricity producers to teachers and the media.

A solar x-ray imager on GOES–12 was made operational in 2003, funded as a USAF–NASA–NOAA partnership, and has provided images of the solar corona at a rate of once per minute. Images are able to show visible coronal changes that signal events on the Sun which will later cause space weather storms. This imager is the first of its kind, and it shows more capability in imaging the Sun for forecasting purposes than any solar imager to date. Automating the extraction of information from these images and incorporating the information into specification and forecast algorithms is already shedding light into the causes of solar wind and eruption events hazarding Earth. However, on the morning of September 2, 2003, the GOES–12 SXI instrument automatically transferred into an instrument safe (non-operational) mode. Two attempts were made to raise instrument voltages to their normal operating levels, but both attempts failed. Development of plans to return the SXI to limited operations is underway.

SEC is also active in developing products and services for the next generation air transport system. Working with both the commercial airlines and the FAA, SEC is formulating new products to serve airline operations of the future. That future is certain to include higher flying and trans-polar air routes as each allows for a faster more profitable trip. Particular issues that are impacted by space weather are navigation, radio communication, and radiation to the passengers and crew. Recent work with the FAA's User Needs Analysis Team (UNAT) has led to the implementation of SEC alerts and warnings into the operational planning for commercial airlines on trans-polar routes. Specifically, communications from air to ground, and the management of the radiation environment are points of concerns for the FAA. SEC has worked to supply the appropriate real-time information to be used by aircraft dispatchers.

CONCLUSION

In conclusion, Mr. Chairman and Members of the Subcommittee, NOAA is pleased to have had the opportunity to provide you an overview of space weather and SEC, our collaborative activities with our partners, and the value of space weather forecasting and research. We look forward to continuing our efforts to provide a critical service for our nation by providing cutting-edge research and forecasts in the space weather arena. I would be happy to answer any questions you may have.

Chairman EHLERS. Colonel Benson.

STATEMENT OF COLONEL CHARLES L. BENSON, COMMANDER, AIR FORCE WEATHER AGENCY

Colonel BENSON. Good morning. I am honored to appear before you today to address this committee on a matter critical to our na-

tion: space weather. I am also pleased to be joined by this distinguished panel of witnesses, including my partner to my right in operational space weather services, Dr. Hildner, Director of the Space Environment Center, otherwise known as SEC, National Oceanic and Atmospheric Administration.

The Air Force Weather Agency, known as AFWA, and SEC operate complementary space weather forecast centers. Over the last several decades in which the Air Force and NOAA have analyzed and forecast space weather for operational users, we have learned a valuable lesson: space weather is complex and costly. Our solution has been to leverage each other's resources, capabilities, and expertise, achieving efficiency by concentrating on those things we each do best. In simplest terms, AFWA is responsible for military and national intelligence support. SEC supports civilian and commercial users.

At AFWA, our focus has been on providing military war fighters and DOD decision-makers with mission-tailored space weather impact products. AFWA is the sole operational space weather support organization in the Department of Defense. To maintain our close working relationship, AFWA has staffed a small contingent of Air Force weather personnel at SEC in Boulder, Colorado since 1972. This operating location acts as a liaison to coordinate data sharing, forecast collaboration, and to develop new forecast techniques. Daily coordination is also accomplished through multiple teleconferences, which assures agreement on joint space weather forecast products.

Another great advantage of our close working relationship with SEC is cost sharing opportunities. For example, the Air Force funded $18 million to develop the Solar X-ray Imager Sensor, now operational on a NOAA satellite. This new sensor now provides critical data to both forecast centers.

Lastly, AFWA relies on real-time data relay and processing, partial backup, and expertise and experience from SEC to provide DOD operators with high quality space weather analysis, forecasts, and warnings.

AFWA aggressively reviewed the space weather operations performed at SEC to determine if AFWA could assume their support responsibilities if the proposed funding cuts are realized. Our initial evaluation shows that there would be many significant challenges transitioning the data ingest, space weather models, applications, and computer and communication infrastructures. Meeting these challenges would be both time-consuming and very costly. In particular, the space weather research and technology transition expertise at SEC would take years to rebuild at AFWA. Furthermore, there are security, policy, and resource issues of great concern, approval to operate and connect to military networks, Armed Forces Title 10 responsibilities providing services to commercial interests, and both manpower and operating fund limitations.

Our Nation is becoming increasingly dependent on space technology. Although the science of space weather is still in its infancy, it has been compared to the meteorological capability of this country in the 1950's, we are on the verge of improved capabilities from new models and data sources, which will provide more accurate space weather services. SEC is at the forefront of this movement.

The Nation's investment in space weather capabilities will yield great future dividends, just as the investment in terrestrial weather 50 years ago is paying off today in the Nation's ability to anticipate extreme weather and then mitigate its effects.

The synergy of the two complementary space weather forecast centers at SEC and AFWA have proven to be a national asset to the security and prosperity of the United States. We urge this committee to advocate for a healthy and stable SEC so this critical capability for military and civilian users will continue into the future.

I look forward to addressing all of your questions later.

[The prepared statement of Colonel Benson follows:]

PREPARED STATEMENT OF COLONEL CHARLES L. BENSON, JR.

Introduction

I am honored to appear before you today to address this committee on a matter critical to our nation: space weather. I am also pleased to be joined today by one of my partners in operational space weather services, Dr. Ernest Hildner, Director of the Space Environment Center (SEC), National Oceanic and Atmospheric Administration (NOAA).

Overview of Air Force Space Weather Services

The Air Force Weather Agency (AFWA) has the sole responsibility to provide military space weather services to all Department of Defense (DOD) agencies and units, as well as to the National Intelligence Community. Our mission is two-fold: to collect space weather data from DOD ground- and space-based sensors; and to provide environmental battlespace awareness through mission-tailored analyses, forecasts, and warnings of mission-impacting space weather to operators, warfighters, planners and decision-makers from command level down to individual units. To accomplish our mission, AFWA operates the Space Weather Operations Center, or Space WOC, the Nation's only military space weather analysis and forecast center, located at Offutt Air Force Base, Nebraska. We also operate a global network of optical and radio solar observatories, and maintain an intercontinental network of space weather sensors feeding data to the Space WOC. AFWA employs sixty-four (64) military and contractor personnel at the Space WOC and other locations, including thirty (30) personnel stationed at the solar observatories around the world. In addition to the personnel costs, AFWA committed $10.9 million dollars in Fiscal Year 2003 to operate, upgrade and improve the Space WOC and solar observatories, and to collect data from DOD ground- and space-based sensor networks. AFWA is dedicated to providing warfighters a complete situational awareness of the battlespace in which they operate. This enables the warfighters to maximize their effectiveness while minimizing the risk to life, resources and mission impacts introduced by the natural space environment.

Users of Air Force Space Weather Products and Information

Users of AFWA's space weather services include every branch of service—Army, Air Force, Navy, Marine Corps and Coast Guard—and the National Intelligence Community, from leadership and senior decision makers to specific individual units. Success in every modern military operation depends upon at least one of the following space weather-impacted capabilities: long-distance radio or satellite communications for command and control, precision navigation and timing from Global Positioning System (GPS) signals, over-the-horizon or tactical radars, high-altitude manned aerial reconnaissance, orbiting spacecraft and sensors, and strategic space launch. AFWA provides analyses and forecasts of space weather impacts on these capabilities to DOD and National Intelligence Community leadership and operators. The National Oceanographic and Atmospheric Administration (NOAA) Space Environment Center (SEC) is a major user of Air Force space weather data. AFWA provides this data in accordance with collaborative partnering agreements to facilitate its space weather support to the commercial and civilian communities.

Relationship Between AFWA, SEC, and NASA

AFWA and SEC are partners in providing space weather service to the Nation. Each has clearly defined roles and responsibilities, leveraging the capabilities of the other to realize significant cost and resource savings. In simplest terms, AFWA is responsible for military and national intelligence support—SEC supports civilian and commercial users. The Air Force divides space weather services into five basic

steps: (1) observe, measure, and collect space weather data, (2) analyze the data, (3) specify and forecast the space environment, (4) tailor analyses and forecasts to meet individual user needs, and (5) integrate space weather information to users' decision and execution processes. AFWA's primary focus on information tailoring and integration are the two steps providing the greatest benefit and value to the warfighter. SEC emphasizes characterization and forecasting the natural space environment.

AFWA relies on SEC in three crucial areas to accomplish our space weather mission: 1) unique data, analyses and forecasts provided by SEC; 2) partial backup capability; and 3) SEC's unique space weather experience and expertise. The Space WOC relies on ground- and space-based magnetometer data provided through SEC to analyze, warn and forecast global geomagnetic activity important to the national intelligence agencies and to the North American Aerospace Defense Command (NORAD). AFWA also depends on alerts of geomagnetic activity from NOAA satellites and solar activity forecasts provided by SEC to warn and forecast impacts to specific military communications links. As identified in the National Space Weather Program Implementation Plan, the AFWA and SEC forecast centers provide limited back-up operations for each other in the event of computer equipment or communication outages. Current back-up consists of telephone notification of observed space weather events. Space WOC and SEC coordinate on forecasts and engage in multiple daily space weather teleconferences. These teleconferences inject valuable insight into the science and art of space weather forecasting and allow AFWA to leverage the vast knowledge and experience of SEC scientists.

AFWA reciprocates in our partnership with SEC by sharing unique DOD space weather data and Air Force forecasts of geomagnetic activity. SEC utilizes solar images and radiographs from the solar observatories, particle data from sensors aboard military satellites, and ground-based DOD instruments in their operations. In addition, every six hours the Space WOC produces a forecast of geomagnetic activity from SEC supplied data. SEC in-turn uses these forecasts in the production of their products and services.

To facilitate and promote our close working relationship, AFWA established Operating Location-P (OL–P) co-located with SEC at Boulder, Colorado. OL–P personnel act as liaisons between SEC and AFWA, coordinate back-up policy and procedures between the two organizations, augment SEC forecaster manning, interact with researchers, ensure smooth and continuous data flow between both forecast centers, assist SEC researchers in establishing new data sources and ground data systems, and take part in developing new space weather forecast techniques benefiting both organizations. The complementary nature of the two missions allows both NOAA and the Air Force to realize cost sharing advantages to acquire needed data. SEC provides the Advanced Composition Explorer real-time tracking data to AFWA. The Air Force paid $18 million to develop the Solar X-ray Imager now operational aboard one of the NOAA Geostationary Operational Environmental Satellites. Additionally, AFWA pays the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) for ground-based space weather data from a global network of GPS receivers.

AFWA taking on the duties of SEC

Air Force Weather Agency aggressively reviewed the space weather operations performed at SEC to determine if AFWA could assume their support responsibilities if proposed funding cuts are realized. Our initial evaluation shows that there are many significant technical challenges transitioning the data ingest, space weather models and applications, and computer and communication infrastructures from SEC to the Space WOC. Meeting these challenges will be both time consuming and costly. Additionally, there are many critical issues and important policy considerations that would have to be addressed prior to assuming any commercial space weather services at AFWA. These include Armed Forces Title 10 responsibilities, security and accreditation affecting AFWA's approval to operate and connect to DOD communication networks, as well as significant manpower and funding resource issues. In particular, SEC's expertise and experience in satellite-based space weather measurements from NOAA spacecraft, and its one-of-a-kind space weather modeling applications, would be very difficult to reproduce at AFWA. The space weather research and technology transition expertise resident at SEC would take years to build at AFWA.

Impacts on Air Force and Military Ops

There would be an immediate and severe impact on military operations if the Space Environment Center no longer existed. Air Force Weather Agency's ability to characterize and forecast the space environment would be dramatically reduced, im-

pacting space situational awareness, satellite and radio communications, space control, precision navigation and strike, high-altitude flight and space operations. Additionally, the loss of a back-up capability for the Space WOC would have serious implication on the AFWA continuity of operations plan. The loss of SEC expertise and decades of experience would likely decrease AFWA's space weather characterization and forecast accuracies. The closure of SEC would also result in a decrease in the rapid transition of new techniques and data sources into space weather forecast operations.

Summary

Over the last several decades in which the Air Force and NOAA have analyzed and forecasted the space environment for operational users, we have learned a valuable lesson: space weather is a complex and costly undertaking. Our solution has been to leverage each other's resources; achieving efficiency by concentrating on those things we each do best. Our nation is becoming increasingly dependent on space technology. Although the science of space weather is still in its infancy—which some have compared to the meteorological capability of this country in the 1950's—we are on the verge of improved capabilities from new models and data sources that will provide more accurate space weather services. SEC is at the forefront of this movement. The Nation's investment in space weather capabilities will yield great future dividends, just as the investment in terrestrial weather fifty years ago is paying off today. The synergy of the two complementary space weather forecast centers at SEC and AFWA has proven to be a national asset to the security and prosperity of the United States. One does not have to look very far to see that the United States is not the only "game in town" when it comes to the exploitation of the space environment. We urge this committee to advocate for a healthy and stable SEC so that this critical capability for military and civilian users will continue into the future.

Chairman EHLERS. Thank you.

Dr. Grunsfeld.

STATEMENT OF DR. JOHN M. GRUNSFELD, CHIEF SCIENTIST, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. GRUNSFELD. Thank you.

Mr. Chairman, Members of the Subcommittee, thank you very much for the opportunity for NASA to testify before you today regarding the importance of space weather forecasting provided by the National Oceanic and Atmospheric Administration Space Environment Center and its impact on NASA programs.

Providing space weather data is an important operational service and has a wide range of customers both within the United States Government and in the private sector. My testimony today will focus on how NASA uses these critical data. I will speak to you both from a position as NASA's Chief Scientist, but also as a member of the Astronaut Corps, the group of folks who are most directly exposed to the effects of space weather, and I should add, those few individuals who have ventured beyond 8,000 meters in altitude on Planet Earth.

Solar wind conditions, solar flares, coronal mass ejections, and subsequent geomagnetic activity, commonly referred to as "space weather," affect many more areas of NASA's activities than most people realize. Space weather can have significant adverse impacts on human health, spacecraft operations by increasing the intensity of the near-Earth radiation environment, the increased atmospheric drag on satellites, disrupting their orientation, reducing their lifetime, degrading UHF and high frequency communications, and the operation of the Global Positioning System signals that we use in our spacecraft. These effect the health of our astronauts in orbit, space engineering and research equipment, orbital altitude

for spacecraft such as the Hubble Space Telescope, and ultimately, we use this information to design our spacecraft.

NASA's space and earth science missions routinely employ real-time forecasts from the NOAA SEC to make decisions regarding data collection, spacecraft operation, and even rocket launches. We use this information in the case of anomalies in spacecraft to determine whether it was space weather related or an engineering cause, and this is an important part of our activities to make sure that we maximize the scientific output of our resources.

The Chandra X-Ray Observatory and the recently launched Space Infrared Telescope Facility both use the SEC resources, observations of solar wind conditions and geomagnetic activity, as critical to their real-time input for spacecraft operations. In fact, in the recent solar activity, we have taken advantage of SEC observations to modify our planning for those scientific spacecraft.

At the NASA Johnson Space Center, the Space Radiation Analysis Group uses data provided by the SEC to determine the radiation environment in which NASA's crewed spacecraft will operate. NOAA has supplied space weather monitoring and forecasting information to NASA for every human space flight mission since Apollo 8. This information affects operational decisions, when to launch a particular mission, and when we would do space walking activities or extra-vehicular activities. Because of this—the information that the SEC provides, we can plan our missions and activities in such a way to minimize the radiation exposure received by astronauts on our vehicles.

Minimizing radiation exposure for Shuttle and International Space Station crews is imperative. NASA has sought the advice of the National Council on Radiation Protection and Measurements concerning radiation exposure limits for our astronauts and uses this advice in setting dosage limits. We are also guided by a principle that we call: "As Low as Reasonably Achievable." Without the data provided by the SEC, NASA would have to reassess its operations to protect against exposure to radiation events occurring without warning. And I should add that during this recent solar activity, we have changed some of our operational procedures based on SEC data to ensure the safety of our astronauts and the International Space Station.

Losing the SEC forecast that supports space flight missions would be like living along a coastal area without any hurricane forecasting capability. You would know the hurricane hit you, but you would have no advanced warning, no ability to take preventive actions, and no idea how strong it would be or how long it would last.

NASA has a long history of cooperation with SEC and its predecessor organizations at NOAA. The partnership has enabled SEC to expand its capabilities to support human space flight missions. We have supported the expansion of SEC services and functionality, specifically in data processing, so that they continue to support our Shuttle and ISS missions.

It is not within NASA's mandate as a research and development agency to provide the operational forecasting services currently provided by the SEC. In addition, the technical capacity, budget, and expertise required to perform this activity could not transition

to NASA without impacting our ongoing space flight research and operations. The NOAA SEC has a unique complement of people, experience, and resources that allows it to provide a high level of service to the space weather customers. There are no other sources, either domestic or foreign, that can provide this type of support. The capability to monitor and forecast this environment should well remain with the agency that has the mission and the proven expertise to respond to all of these customers.

Thank you.

[The prepared statement of Dr. Grunsfeld follows:]

PREPARED STATEMENT OF JOHN M. GRUNSFELD

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to testify before you today regarding the importance of space weather forecasting provided by the National Oceanic and Atmospheric Administration (NOAA) Space Environment Center (SEC) and its impact on NASA's programs. Providing space weather data is an important operational service, and it has a wide range of customers, both within the United States Government and in the private sector. My testimony today will focus on how NASA uses these critical data. I will speak to you from my perspective both as NASA's Chief Scientist, and as a member of the astronaut corps—the group of people most directly exposed to the effects of space weather.

Solar wind conditions, solar flares, coronal mass ejections (CMEs), solar extreme ultraviolet emissions, and subsequent geomagnetic activity, commonly referred to as "space weather," affect many more areas of NASA operations and programs than most people realize. Space weather can have significant adverse effects on human health and spacecraft operations by increasing the intensity of the near-Earth radiation environment, increasing atmospheric drag, disrupting satellite orientation, and degrading UHF and HF communications and Global Positioning System (GPS) signals. These affect the health of our astronauts in orbit, space engineering and research equipment functionality, orbital attitude for spacecraft such as the Hubble Space Telescope, and ultimately, the way we design spacecraft.

NASA's Space and Earth Science missions routinely employ real-time forecasts from the NOAA SEC to make decisions regarding data collection, spacecraft operations, and rocket launches. NASA engineers and researchers use near, real-time SEC forecasts to analyze instrument and spacecraft anomalies, and separate cause and effect in the highly modulated environment of space. During solar-induced changes to the near-Earth radiation environment, NASA's in-space research instrumentation can become saturated by solar energetic particles, which can lead to anomalies. This has happened numerous times during the recent maximum phase of the solar cycle. One example comes from the Earth Science Mission Operations (ESMO) Project. The ESMO uses data provided by the NOAA SEC to determine whether spacecraft anomalies are the result of system malfunctions or space weather events. Being able to determine quickly that an anomaly was caused by space weather allows ESMO to avoid lengthy equipment shutdowns while engineers search for a cause. NOAA SEC is the only operational source for accurate, real-time information on the near-Earth space radiation environment. NASA uses the lessons learned from these experiences and the database of radiation measurements gathered by SEC to design spacecraft with more robust systems that can withstand space weather events.

The Chandra X-Ray Observatory and the recently launched Space Infrared Telescope Facility both use the SEC observations of solar wind conditions and geomagnetic activity as a critical input to their real-time models of the Earth's radiation environment. These models allow us to adjust our operations to mitigate sensor degradation and data loss. The result is that NASA is able to ensure optimal scientific return from these two flagship missions. The SEC observations are also crucial to NASA-funded research exploring the Sun-Earth connection. The Sun affects the entire solar system, including all scientific data collection satellites.

At the NASA Johnson Space Center, the Space Radiation Analysis Group (SRAG) uses data provided by the SEC to determine the radiation environment in which NASA's crewed spacecraft will operate. NOAA has supplied space weather monitoring and forecasting information to NASA for every human space flight mission since Apollo 8. This information affects operational decisions, such as when to launch a particular Shuttle mission and when extra-vehicular activities (EVAs) can be safely conducted. Because of the information that the SEC provides, we can plan

missions and on-orbit activities in such a way as to minimize the radiation exposure received by our astronauts and our vehicles.

Minimizing radiation exposure for Shuttle and International Space Station crews is imperative. NASA has sought the advice of the National Council on Radiation Protection and Measurements concerning radiation exposure limits for our astronauts, and uses this advice in setting radiation dosage limits. NASA's radiation protection efforts are further guided by the ALARA (As Low as Reasonably Achievable) principle. Without the data provided by SEC, NASA would have to reassess its operations to protect against exposure to radiation events occurring without warning.

Losing the SEC forecast that support space flight missions would be like living along a coastal area without any hurricane forecasting capability. You would know when the hurricane hit you, but you would have no advanced warning, no ability to take preventive actions, and no idea how strong it would be or how long it would last.

The risk that radiation poses to our spacecraft and astronauts is borne out by past examples. For instance, in 1989 significant solar events impacted both the Space Shuttle and the Mir space station, along with other uncrewed spacecraft. In the spring of 1989, a solar flare, solar particle event, and a geomagnetic storm doubled the daily radiation dose for the Mir crew for two days, with elevated levels lasting for two weeks. The solar events increased atmospheric drag during the first day of STS–29. NORAD lost track of several space objects for time periods varying from days to weeks. Several satellites lost attitude control, while others tumbled. These space weather events also brought the northeastern United States' power grid close to collapse. In the fall of 1989, a second series of solar particle events again raised the dose of the Mir crew and damaged satellite solar arrays.

The information provided by SEC is critical to NASA today as we operate the ISS until the Space Shuttle returns to flight. NASA has some monitoring capability on the ISS that we rely upon to gauge the safety of the ISS environment for the crew. Although we have tools that allow us to measure the radiation exposure of the crew and vehicle on a periodic basis, we cannot monitor it constantly. This equipment was designed as a back-up to the radiation monitoring and forecasting data provided by SEC, which allow flight controllers to notify the crew of increased radiation exposure levels. The SEC provides NASA with critical real-time monitoring and forecasting of the radiation environment around the Earth. We use this information along with on board instrumentation to assess the ISS radiation environment. In the current solar event, SEC forecasts gave us sufficient warning of a proton flux event to allow the ISS crew to shelter in areas of the ISS which provide more shielding protection from radiation.

NASA has a long history of cooperation with SEC and its predecessor organizations at NOAA. That partnership has enabled SEC to expand its capabilities to support human space flight missions. In the 1960s, NASA funded the development of the Solar Particle Alert Network (SPAN) to support the Apollo missions. NASA also supported the expansion of SEC services to support our Skylab missions. Most recently, we have helped SEC to modernize and add functionality to its data processing systems so that they can continue to support our Shuttle and ISS missions.

Building on the information and analysis provided by SEC, we have expanded our understanding of the impact of space weather on NASA's operations, and our ability to predict and respond to significant events. It is only in the past decade that we have realized that geomagnetic activity can enhance the outer electron belt, and increase radiation exposure for astronauts performing EVAs. During the same period, we have learned the important of CMEs with regard to solar flares in producing large proton events that can pose health risks to astronauts on orbit. NASA' Solar and Heliospheric Observatory (SOHO) has revolutionized our understanding of CMEs, providing real-time images of CMEs coming toward Earth. Perhaps most significantly, in the last several years, we have discovered definitive evidence of the magnitude and frequency of very large solar particle events over the past 400 years. These events were significantly larger than anything we have witnessed since humans started flying in space. It is likely that we will see a recurrence of solar particle events of a similar magnitude.

It is not within NASA's mandate as a research and development agency to provide the operational forecasting services currently provided by the SEC. In addition, the technical capacity, budget and expertise required to perform this activity could not transition to NASA without impacting our other ongoing space flight operations and research.

The NOAA SEC has a unique complement of people, experience, and resources that allows it to provide a high level of service to its space weather customers. There are no other sources, either domestic or foreign, that can provide this type of support. As the United States continues to expand its reliance on space-based assets

such as GPS, cellular communications, and digital satellite technology, the importance of understanding the space weather environment becomes even more critical. The capability to monitor and forecast this environment should remain with the agency that has the mission and the proven expertise to respond to all of these customers.

I sincerely appreciate the forum that the Subcommittee provided today to highlight the importance of space weather forecasting, and I look forward to the opportunity to respond to your questions.

Chairman EHLERS. And I thank you.

And I apologize for the bells ringing. We have not one, not two, but three votes on the Floor. I would estimate it will take us approximately a half an hour total. So we will recess at this point at the call of the Chair and return as soon as possible after the third vote. And I apologize to you for the interruption. The Committee is in recess.

[Recess.]

Chairman EHLERS. The Committee will come to order. I apologize that it took longer. The—we are having some political problems, which I know is very hard for you to believe. But we are hoping to pass the supplemental appropriation today, and there are some very strong feelings on both sides, so we have had some delay motions and votes.

We will proceed now with Mr. Kappenman.

STATEMENT OF MR. JOHN G. KAPPENMAN, MANAGER, APPLIED POWER SYSTEMS, METATECH CORPORATION

Mr. KAPPENMAN. Thank you, Mr. Chairman and Committee Members.

I am here to represent the viewpoint of the electric power industry and the important threat that geomagnetic storms pose to this critical national infrastructure and the importance of the Space Environment Center forecasting and forecasting services that are rendered to the power industry for this important threat.

You have posed a number of very important questions. I will try and briefly cover the highlights of those, although I do provide more detail in the prepared testimony. The first question is the historic impacts of these large storms. And I will give you a very brief overview of a storm that occurred about 14 years ago, and in fact, was the last geomagnetic super storm that occurred and the nature of the impacts that were felt in North America on the power grid for that storm.

If we can start an animation here.

[Video]

This is just showing you 20 minutes of what I would call very bad space weather that day. And the important feature of this type of weather is that it is unlike terrestrial weather. You are seeing sudden onsets, planetary, continental impacts and—of that moving at phenomenal rates of speed.

Power systems are built to withstand certain types of weather, mostly terrestrial weather, but that is very regionally confined when it is severe. This sort of severe weather has, truly, a continental footprint, and that presents a very unique challenge to operations of power grids. In fact, the next slide here—I will start up an animation.

[Video]

These are the impacts that were observed by the U.S. power grid or North American power grid coincident with that previous 20 minutes of bad space weather. And in the case of Quebec itself, the entire province experienced a blackout from this brief period of activity. And in fact, the power system operators that day—this was the worst day of your life if you are a power system operator, because things happen so quickly. You have very little time to intervene. In the case of Hydro Quebec, they went from normal operating conditions to complete province-wide blackout in 92 seconds: no time to even assess what was going on, let alone try and do any sort of meaningful human intervention. Later on that day, if we will start up this animation, the storm got even more intense.

[Video]

And as you can see, it was well down into and across the entire U.S. for this 40-minute duration shown here. This storm lasted in excess of a day. And I am just showing you a few of the highlights from this activity. If we can go for—here we go.

[Video]

If we start up this animation, for that previous storm activity, this is what was observed in the U.S. as far as important power system operating anomalies. We barely hung on to the system in retrospect, the postmortems. Everybody agrees. We came very, very close to experiencing a very—potentially very widespread power system collapse that could have occurred in the U.S. that day.

The second question you posed, forecasts and how are they used. The short answer, power grids certainly do have operational procedures that they put in place in times of geomagnetic storms. They have both prepared actions that they do from advanced forecasts as well as actions that they do from nowcasts and updates on a continuous basis. These are provided, of course, from SEC or from commercial providers, like my company, that depend greatly on SEC data to provide even more detailed forecasts of what could occur.

The nature of recent discoveries was also asked. We certainly have learned a lot about the threat that is posed to the U.S. power grid infrastructure by space weather over the past few years. We certainly, and I imagine your constituents know, that—post-August 14 of this year that there is an awareness that there has been a decline in power grid infrastructure and investment. And that has done nothing but increase our vulnerability to space weather since that March '89 storm.

We know, also, that storms can be, perhaps, three to ten times larger in magnitude than what occurred in March '89 and that large U.S. blackouts are possible.

[Slide]

This is just one of many scenarios that we have studied for regions that could be blacked out. We are looking at the potential of blackouts that could exceed even that of the very large blackout that occurred just a few months ago. And there is no part of the U.S. power grid that is immune to this. It is just a matter of where does this intense phenomenon geographically lay down? How big is the footprint? And we know these footprints can be very, very large. And literally, we could impact over 100 million population in the worst case scenarios.

If there is no Center, clearly this would degrade the ability to counter some of the important impacts.

Thank you.

[The prepared statement of Mr. Kappenman follows:]

PREPARED STATEMENT OF JOHN G. KAPPENMAN

The Vulnerability of the U.S. Electric Power Grid to Space Weather and the Role of Space Weather Forecasting

I am grateful for the Committee's kind invitation to offer testimony today on "What Is Space Weather and Who Should Forecast It?" as the answer to this important question has many possible implications and places the Nation at an important crossroad. It is only fitting that we carefully consider the future path that is in the best interests of the Nation. And as I hope to emphasize in my testimony, these space weather concerns, especially in regards to impacts on electric power grids, may pose important homeland security and energy security concerns and should be considered in your deliberations.

BACKGROUND

For the past 27 years, I have been an active researcher and observer of electric power system impacts caused by the widespread geomagnetic field disturbances due to Space Weather. For some 22 years, these activities occurred while I was employed in the electric power industry itself. I not only lead research investigations funded by my employer, but also efforts funded by the Electric Power Research Institute. My areas of responsibility involved the design and development of the high voltage transmission network and one of our pressing concerns was the unique problems posed by the natural phenomena of Space Weather. This was a problem that we recognized was of a growing and evolving nature as our industry continued to grow in size and technological sophistication. I particularly became engaged with the NOAA–SEC in the aftermath of the great geomagnetic storm of March 13–14, 1989, a storm which produced historic impacts to the operations of power grids in the U.S. and around the world. I was part of an electric power industry group that advocated the efforts such as the ACE satellite and resulting solar wind monitoring that have greatly improved the Nation's capability to provide accurate short-term forecasts of severe geomagnetic storm events.

Since 1997, I have subsequently been employed with the Metatech Corporation and a part of what we now do is heavily involved with Space Weather and impacts on technology systems, particularly large power grids. Our company has, in fact, been involved in the vulnerability and risk assessment for the power grids in England and Wales, Norway, Sweden and portions of Japan. Metatech also provides continuous space weather forecasting services for the company that operates the electric power grid for England and Wales. Since May 2002, Metatech has been providing similar vulnerability and risk assessments for the U.S. electric power grid to the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP Commission). The EMP Commission was established by Congress under the provisions of the Floyd D. Spence Defense Authorization Act of 2001, Public Law 106–398, Title XIV. The EMP Commission was chartered to conduct a study of the potential consequences of a high altitude nuclear detonation on the domestic and military infrastructure and to issue a report containing its findings and recommendations to the Congress, the Secretary of Defense, and the Director, FEMA. While the charter of this commission involved intentional electromagnetic attack on the U.S. infrastructures primarily from a high altitude nuclear burst, the MHD (or magneto hydro dynamic) portion of this electromagnetic attack can be remarkably similar to the electromagnetic disturbance caused by the natural phenomena of Space Weather. As a result the Commission wisely investigated the plausible impacts due to severe geomagnetic storms on the U.S. electric power infrastructure. The Commission has also closely coordinated with the NERC (North American Electric Reliability Council) and their Critical Infrastructure Protection Advisory Group (CIPAG). This group has been continuously and fully vetted on the findings of the Commission directed investigations. While the Commission is not scheduled to report their findings back to Congress until approximately March of 2004, they have encouraged Metatech to freely share with the scientific community the investigation results related to severe geomagnetic storm events. As a result, as part of my prepared testimony, I will also provide the significant portions of these findings. However, at this point, I should caution that these reports will only be the opinion of

Metatech as the Commission has not completed deliberations and will not formally issue findings until early next year.

In these diverse and various capacities, it has been my privilege to work with the NOAA–SEC for many years as an end-user of their forecast services, a bulk data user and, in some degrees, a competitor to the SEC. In all cases we have developed a close partnership with this agency and its staff, a relationship that has clearly allowed for key advances in improving the geomagnetic storm forecasting capability for the electric power industry.

Space Weather, Impacts to Electric Power Systems and the Importance of Forecasting Services

The Committee has posed four questions which are designed to probe the topic area of Space Weather Forecasting Services and their importance to the reliability of the Nation's electric power grid. I shall attempt to answer these through examples of historic events, examination of developing trends and operational procedures, and efforts that have been made to model and extrapolate implications for severe storm scenarios.

Question 1. Please provide an overview of how space weather can affect electric power grid systems, including examples of historical events that have caused problems.

Space Weather is associated with ejection of charged particles from the Sun, which after colliding with the Earth's magnetosphere will produce significant disturbances in the normally quiescent geomagnetic field at the Earth's surface. These disturbances have caused catastrophic impacts to technology systems in the past (e.g., the power blackout in Quebec in March 1989). More importantly, as detailed examinations have been undertaken concerning the interaction of geomagnetic storm environments with power grids and similar infrastructures, the realization has developed that these infrastructures are becoming more vulnerable to disruption from electromagnetic interactions for a wide variety of reasons. This trend line suggests that even more severe impacts can occur in the future for reoccurrences of large storms.

An Overview of the U.S. Electric Power Grid

While electricity customers receive power from the local distribution system (typical operating voltage of 15kV with step down to 120/240 volt), the backbone of the system is the high voltage transmission network. The primary AC transmission network voltages in the U.S. are at 230kV, 345kV, 500kV and 765kV. These transmission lines and their associated transformers serve as the long distance heavy hauling arteries of electricity production in the U.S. A single 765kV transmission line can carry over 2000 MW of power, nearly 200 times what a typical 15kV distribution line which is the overhead line commonly used for residential distribution. Space Weather or geomagnetic disturbances directly attack this same high voltage transmission circulatory system and because both have continental footprints, these disturbances can rapidly erode reliability of these infrastructures and can therefore threaten widespread blackout for extreme disturbance events. The U.S. electric power grid is the world's most extensive, Figure 1 provides a map of the approximate location of the nearly 80,000 miles of 345kV, 500kV and 765kV transmission lines in the contiguous U.S.

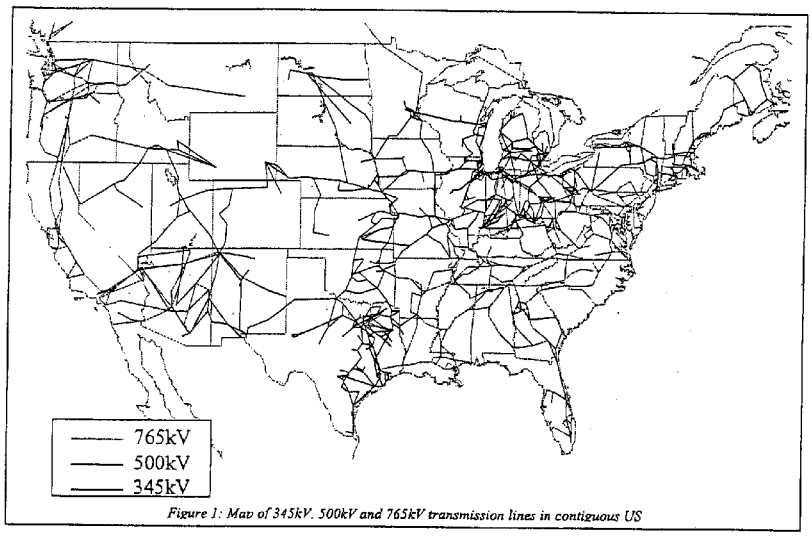


Figure 1: Map of 345kV, 500kV and 765kV transmission lines in contiguous US

These geographically wide spread assets are also fully exposed to the extremes of the terrestrial environments. Because these assets are the critical backbone of the system, utility company engineers have taken great care to engineer for robust capabilities of these assets to withstand most of the severe wind, lightning and ice loading exposures. For example, while many of the low voltage local distribution feeders can fail due to tree damage during hurricanes, these same hurricane events rarely threaten the integrity of the high voltage grid itself. While extensive attention has been paid to these assets for terrestrial weather exposures, a multitude of design decisions has inadvertently and significantly increased the power grid exposure and vulnerability to space weather environments, as will be discussed in later sections of this testimony. There are "no shortages" of challenges that these systems face. In addition to the terrestrial weather challenges, power company operators face even more ominous threats from the recent realization of physical and cyber terrorism. In spite of the best efforts, failures still can occur; for example, a lighting strike can still cause on occasion a high voltage transmission line to trip. Very high winds, for example, due to a tornado can cause the failure of a line or several lines on a common corridor. However, most of these events generally occur in isolation and power grids are operated at all times to withstand the largest creditable single contingency failure without causing a cascading collapse of the network itself. Space Weather differs from ordinary weather in that it has a big footprint and attacks the system across many points simultaneously, causing at times of severe events multi-point failures on the network that can threaten the integrity of the network. Therefore, geomagnetic storms may be one of the most important hazards and is certainly the least understood threat that could be posed to the reliable operation of these networks.

The transmission lines and substations are all geographically remote and unstaffed facilities. They are difficult to fully monitor and cannot be continuously patrolled. The bulk of the protection of these facilities are done via autonomous relays that continuously sense for disturbance conditions and operate as quickly as 70 msec to trip off or isolate an asset that is sensed as an operating outside of acceptable parameters to protect the integrity of the network as a whole. Real-time data from a limited number of monitoring points is brought back to one of the more than 150 continuously-staffed control centers used to operate the transmission infrastructure in the U.S. There operators continually assess network conditions and make needed adjustments to keep all flows and voltages within prescribed boundaries and limits. Further they are responsible to dispatch generation (in many cases within a market-based supply system) to perfectly balance the production and demand for electric energy. The limited amount of real-time data makes it a challenge to fully assess the many possible threats that can occur to these remote assets. The remotely monitored data is not at all times unambiguous and can lead to differing

interpretations. Therefore it is not easy to determine the nature of a threat from this alarm level information alone. In most control centers, the real-time data is typically augmented with continuous high quality terrestrial weather information, as regional storms and climatic events can be one of the most frequent sources of operational anomalies on the network. The power industry is just now getting to the point of being introduced to the same paradigm in regards to high quality space weather data and the benefits it could offer in improving situational assessments.

The Electric Power Infrastructure and Its Sensitivity to Disturbance Levels

While more details will be provided later, a brief overview of how these geomagnetic disturbance environments actually interact with large regional power grids indicates the complex nature of the threat. When these disturbances occur they result in slowly varying (1–1000 seconds) changes in the geomagnetic fields that can have very large geographic footprints. These magnetic field disturbances will induce electric fields in the Earth over these same large regions. Across the U.S., complex topologies of long distance transmission lines have been built. These grids include transformers at generating plants and substations that have grounded neutrals. These transformer neutrals provide a path from the network to ground for these slowly varying electric fields (less than 1 Hz) to induce a current flow through the network phase wires and transformers.

These currents (known as geomagnetically-induced currents—GICs) are generally on the order of 10's to 100's of amperes during a geomagnetic storm. Though these quasi-DC currents are small compared to the normal AC current flows in the network, they have very large impacts upon the operation of transformers in the network. Under normal conditions, even the largest transformer requires only a few amperes of AC excitation current to energize its magnetic circuit, which provides the transformation from one operating voltage to another. GIC, when present, also acts as an excitation current for these magnetic circuits, therefore GIC levels of only 1 to 10 amperes can initiate magnetic core saturation in an exposed transformer. This transformer saturation from just a few amperes of GIC in modern transformers can cause increased and highly distorted AC current flows of as much as several hundred amperes leading to overloading and voltage regulation problems throughout the network.

Power networks for decades have been operated using what is termed an "N–1" operation criteria. That is, the system must always be operated to withstand the next credible disturbance contingency without causing a cascading collapse of the system as a whole. Therefore, when a single-point failure occurs, the system may need to be rapidly adjusted to be positioned to survive the next possible contingency. Space Weather disturbances have already been shown to cause near simultaneous multi-point failures in power system infrastructures, allowing little or no time for meaningful human interventions. The onset of severe geomagnetic field disturbances can be both sudden and have continental footprints, placing stresses broadly across power grid infrastructures.

When a transformer saturates, it can produce a number of simultaneous and undesired impacts to the grid. If the spatial coverage of the disturbance is large, many transformers (hundreds to thousands) will be simultaneously saturated. The principal concern to network reliability is due to increased reactive power demands from transformers that can cause voltage regulation problems, a situation that can rapidly escalate into a grid-wide voltage collapse. But a nearly equal concern arises from collateral impacts stemming from highly distorted waveforms (rich in harmonics) from saturated transformers that are injected into the network. As previously mentioned protective relays continuously sense these now distorted signals. These distortions can cause a mis-operation of an exposed relay causing it to operate to isolate a key element of the network. When these relay mis-operations occur in-mass because of the big footprint of a storm, the protection systems can rapidly destroy the integrity of the network that the relays were intended to protect. In addition, individual transformers may be damaged from overheating due to this unusual mode of operation, which can result in long-term outages to key transformers in the network.

The threats to the infrastructure from geomagnetic storms include the possibility of widespread power blackouts, damage to expensive and difficult to replace transformers, and damage to equipment connected to the grid. As a result, an important aspect of concern is the time required to replace damaged transformers and to fully restore the operation of the power grid.

Historic Storm Events and Power System Impacts

The rate of change of the magnetic field is a major factor in creating electric fields in the Earth and thereby inducing quasi-dc GIC current flow in the power trans-

mission network. Therefore an important means of classifying the severity of a disturbance can be made by noting the dB/dt or rate-of-change of the geomagnetic field (usually measured in units of nanotesla per minute of nT/min). The larger this dB/dt environment becomes, the larger the resultant levels of GIC and levels of operational impact upon exposed power grids.

Some of the first reports of operational impacts to power systems date back to the early 1940's and the level of impacts have been progressively become more frequent and significant as growth and development of technology has occurred in this infrastructure. In more contemporary times, major power system impacts in the U.S. have occurred in storms in 1957, 1958, 1968, 1970, 1972, 1974, 1979, 1982, 1983, and 1989 and several times in 1991. Smaller scale impacts can and do occur even more frequently; these include anomalous operating events that may result in the unexpected tripping of a key element of the system or even permanent damage to apparatus such as large power transformers.

In order to understand the far reaching impacts of large geomagnetic storms, the disturbance impacts in particular of the great storm of March 13–14, 1989 are reviewed in some detail. The most important of these impacts was the storm-caused chain of events resulted in the blackout of the Hydro-Quebec power system. At 2:42 am EST, all operations across Quebec, Canada were normal. At 2:43 am EST, a large impulse in the Earth's magnetic field erupted along the U.S./Canadian border. GICs immediately started to flow in the southern portions of the Hydro-Quebec grid. In reaction to the GIC, voltage on the network began to sag as the storm increased in magnitude; automatic voltage compensating devices in the network rapidly turned "on" to correct this voltage imbalance. Unfortunately these compensators themselves were vulnerable to the harmonics generated in the network's transformers, and mis-operation of relays to protect these devices caused the entire fleet of 7 compensators on the network to shut down within 60 seconds of the beginning of the storm impulse. When the compensators shut down, the network collapse followed within a matter of seconds, putting over 6 million inhabitants of the province in the dark. Going from normal conditions to a complete province-wide blackout occurred in an elapsed time of just 90 seconds. The power system operators had no time to understand what was happening, let alone to take any meaningful human action to intervene and save the grid. In comparison, the August 14, 2003 blackout covering large portions of the U.S. and Canada evolved over a period of time in excess of 90 minutes. Figure 2 provides a four minute sequence of maps showing the onset of observed geomagnetic field disturbance conditions that caused the Hydro-Quebec blackout.

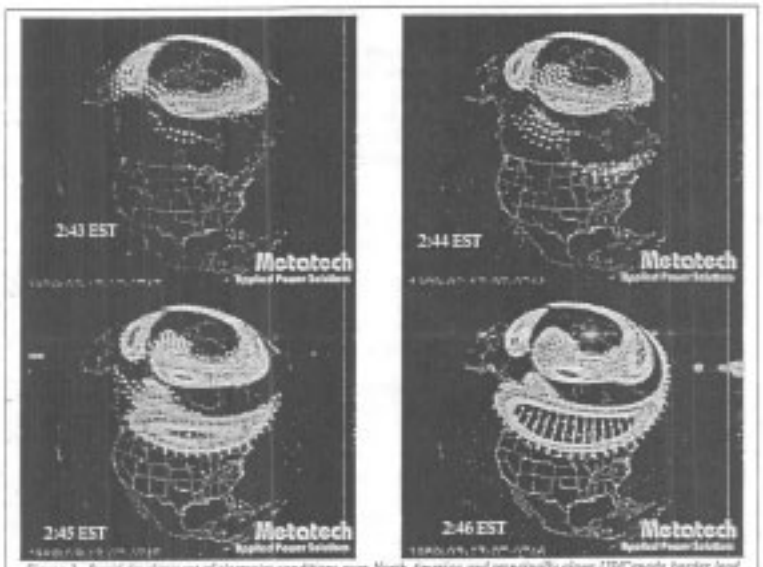


Figure 2. Rapid development of electrojet conditions over North America and principally along US/Canada border lead to Hydro Quebec collapse and other reported problems in Minnesota, Manitoba and Ontario at these times. These images depict the ground level geomagnetic reconfiguration from over 4 Minutes from 2:43 – 2:48 EST

Over the next 24 hours, five additional magnetic disturbances propagated across the continent and nearly toppled power systems from the Midwest to the mid-Atlantic regions of the U.S. The North American Reliability Council (NERC), in their post analysis, attributed ~200 significant anomalies across the continent to this one storm. Figure 3 illustrates the geographic breadth of power system problems during one of the five substorm time periods on March 13, 1989 across the North American grid. Figure 4 provides a depiction of the geographic extent of the geomagnetic field disturbance conditions across North America at time 22:00UT, that triggered the events shown in Figure 3. As illustrated, at this time intense geomagnetic field disturbances extended into mid-latitude portions of North America and essentially across the entire U.S.

For further reference, a list of the NERC reported power system operating anomalies due to this storm is provided in Exhibit 1. The North American Electric Reliability Council, at that time, would annually review significant system disturbances and provided a report on the most important of these system disturbances, in order to share information and insights on the disturbances and what lessons may be gained from these experiences. The 1989 System Disturbances report included discussions on the San Francisco Bay Area Earthquake, the impacts of Hurricane Hugo, and several other disturbances, most of which were tied to extreme environment disturbances. This report also provided a detailed discussion of the March 13–14, 1989 Geomagnetic Superstorm, which entailed ~50 percent of the entire 67 page NERC report. This Exhibit from that report provides an indication of the wide spread impacts that were observed across the continental power grid.

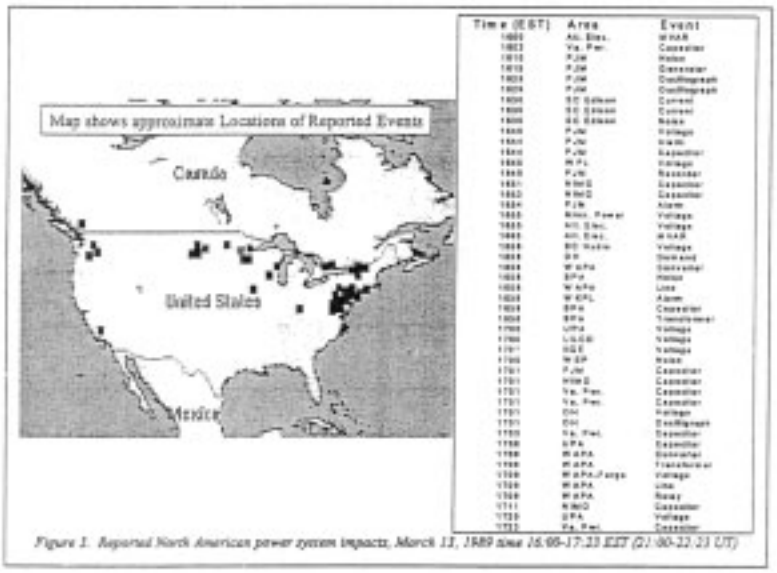


Figure 3. Reported North American power system impacts, March 13, 1989 time 16:00-17:23 EST (21:00-22:23 UT)

Figure 4. Estimated regions of observed geomagnetic field disturbance conditions at 22:00UT, March 13, 1989

As previously mentioned, the best means of characterizing the geomagnetic field disturbance environment as it relates to GIC impacts on power grids is by the rate-of-change or dB/dt in nT/min. Figure 5 provides a plot of the dB/dt (or RGI—Regional GIC Index) observed at the Ottawa observatory which would have broadly

characterized the intensity of the disturbance over the general New York, New England regions and neighboring portions of southern Ontario and Quebec in Canada.

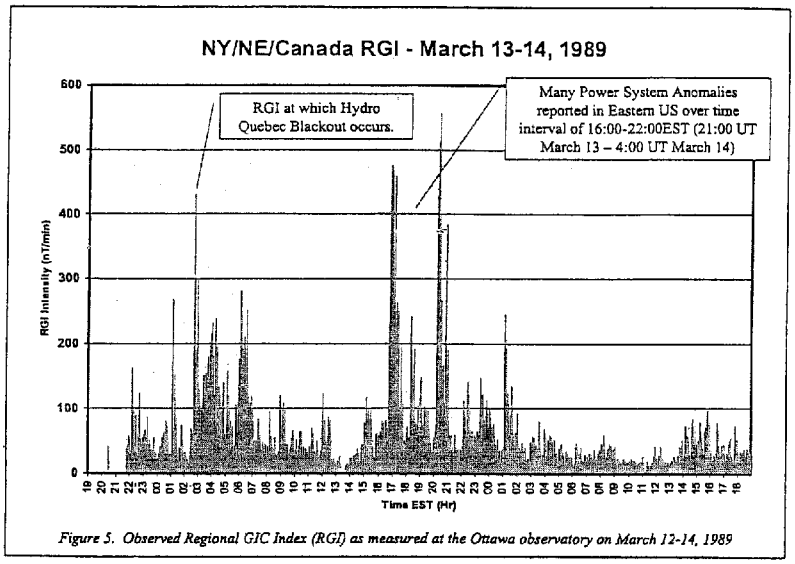


Figure 5. Observed Regional GIC Index (RGI) as measured at the Ottawa observatory on March 12-14, 1989

As shown, the disturbance intensity that triggered the Hydro-Quebec collapse at 2:45 EST was at an intensity of ~480 nT/min. Over the time interval of power system events shown in Figure 3, the peak dB/dt disturbance intensities observed in various other locations across the U.S. are provided in Figure 6. As shown, many of these disturbances were initiated by disturbance intensities that generally ranged between 300 and 600 nT/min.

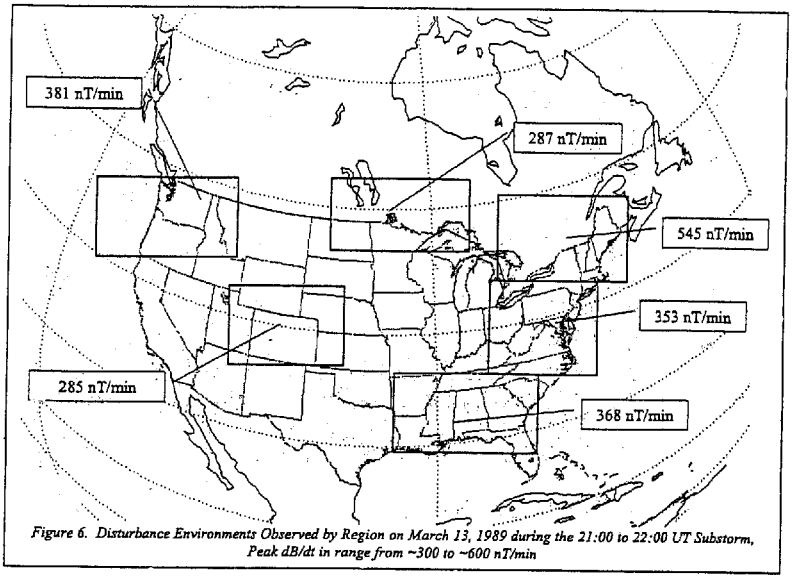


Figure 6. Disturbance Environments Observed by Region on March 13, 1989 during the 21:00 to 22:00 UT Substorm, Peak dB/dt in range from ~300 to ~600 nT/min

While power grid reliability concerns are of paramount importance, the long duration of the storm and associated GICs in transformers on the network caused internal transformer heating to the point of failure. There were several noteworthy cases of transformer internal heating associated with the March 13, 1989 storm in the U.S. mid-Atlantic Region. In one case at the Salem Nuclear plant in southern New Jersey, the internal heating was so severe that complete failure of the transformer resulted. Figure 7 provides a few pictures of the transformer and internal winding damage (conductor melting and insulation burns) due to the GIC exposure. In this case the entire nuclear plant was unable to operate until the large 500kV ~1200MVA transformer was replaced. Fortunately a spare from a canceled nuclear plant in Washington State was available and restoration of the plant occurred in ~40 days. Transformers of this type are of custom design and in most cases new replacement transformers of this type generally take up to a year for delivery. Failures of key apparatus, such as this, raise concerns about the ability to rapidly restore power in a region once a blackout and failure has occurred.

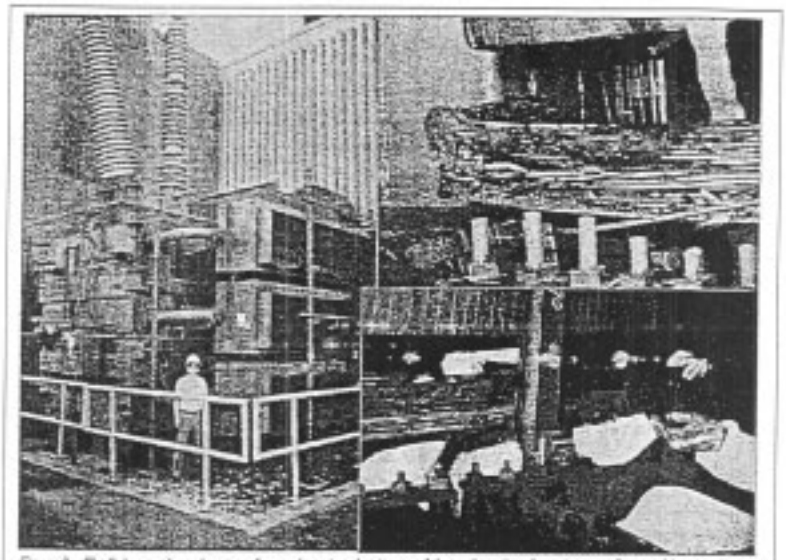


Figure 7 – The Salem nuclear plant transformer (exterior shot is one of three phases) and two images of internal heating damage to conductors and insulation from stray flux heating caused by GIC-induced half-cycle saturation of the transformer occurring during the March 13-14, 1989 Superstorm.

Question 2. How does your organization use data and products from NOAA's Space Environment Center (SEC)? In general, how much lead time do, you need to make decisions for mitigating the effects of space weather?

As I had previously discussed, I have had considerable experience both as an electric power industry user of data and products from the NOAA Space Environment Center as well as a provider of geomagnetic storm forecast services to electric power industry end-users. Therefore, if the Committee will allow me, I will attempt to answer this question from both points of perspective.

Electric Power Industry Application of Forecast Services

Some of the formative research and investigation of problems due to GIC in the power industry was undertaken by my colleague and mentor Professor Vernon D. Albertson at the University of Minnesota starting in the late 1960's. As a result of this work, formal arrangements were made to disseminate geomagnetic storm information provided by the U.S. government (the SEC or forerunner in that era) through established communication means used to make coordinated adjustments in power grid frequency regulation for purposes of time error correction. AEP at that time acted as the official point of contact for these notifications from NOAA as noted in this circa 1987 NERC document provided in Exhibit 2. The March 1989 storm was the first storm to precipitate a large-scale blackout and very nearly threatened

even wider scale problems across the U.S. This unprecedented level of impacts caused renewed emphasis on updating and revising operational procedures to better contend with the unknowns of the disturbance environments. In fact, several example procedures for power pools heavily impacted by the March 1989 storm were published by NERC in the 1989 Disturbances Report as shown in Exhibit 3. These procedures and the regions they encompass include the NPCC, PJM, WAPA, and the Allegheny Power Service Corporation.

Overtime, these procedures have been continuously updated and current examples are provided for the PJM, NPCC, WSCC and even an updated reference document by the NERC as recent as July 17, 2003 and contemporaneous with the EMP Commission efforts to vet the NERC on U.S. Electric Power Grid vulnerabilities to large geomagnetic disturbances. These examples are provided as Exhibits 4 to 7. These procedures describe some of the actions that operators would undertake to better prepare the system to contend with the anticipated stress caused by a storm. Even in the immediate aftermath of the March 1989 storm, the power industry came to recognize the need for predictive forecast warnings of these important storm events. In July 1990 the NERC Board of Trustees issued a position statement advocating forecast technologies that could provide approximately an hour advance notice of the occurrence of important storm events (see Exhibit 8).

Metatech and Other Commercially-Provided Forecasting Services for the Electric Power Industry

Because the NOAA–SEC provides only a broad and generic level of service to end-users of space weather forecasts, these services are not well formatted to extrapolate the possible and plausible impacts that may result to complex technology systems such as electric power grids. As a result, a need has developed and is being successfully filled by the private sector to provide highly specialized forecast services to these complex end-users. At present this service sector is in a state of infancy, but is generally developing much along the model of the medical services community. In this case, the NOAA–SEC forecasts are the equivalent of the general practitioner, for those end-users who have good space weather health (or at least suffer no serious space weather problems); this service may be quite adequate. However for end-users that have serious space weather health concerns, a more specialized care or level of service may be warranted and in most cases can be readily provided by firms such as ours that have specialized capabilities for these unique and complex problems. That being said, it should also be emphasized that end-user lack of awareness of potential space weather problems is a serious challenge that both the SEC and commercial providers must overcome. Exhibit 9 is a technical paper which provides some commentary and overview on the type of specialized services that our company can and does provide to the electric power industry. The relevant portions of this paper discussing these forecast services start on approximately page 23 of the Exhibit. Metatech provides notifications that range from several days in advance based upon solar observations to short-term forecasts that can be on average an hour in advance driven by solar wind observations. We also provide continuous real-time observations as well to verify impacts that are being caused by a storm occurrence. We work extensively and very closely with our clients on their complex needs. These efforts can entail hardening their system from a design perspective, to training of system operators to operationally prepare their system to better respond to anticipated and observed storm related stresses.

Even with these commercial capabilities, the NOAA–SEC provides some of the key data sources that become the input data that are used to drive these sophisticated forecast systems and services. Of necessity, the relationship between NOAA–SEC and the Commercial Providers is one that is highly symbiotic; it that the Commercial Providers greatly depend on the SEC for high quality data and data interpretations, while the SEC looks to the commercial specialists to provide the more specialized services that heavily impacted users may need. Therefore, the loss of the NOAA–SEC would have the almost immediate impact of causing the crumbling of much of the forecasting services capability of the Nation.

Question 3. How would you compare our knowledge today of the impacts of space weather on electric power grid systems to what we knew five years ago, and to what we expect to know five years from now?

New York ISO CEO William J. Museler in the aftermath of the August 14, 2003 Blackout, "the blackout could have damaged the power plants or transmission lines," "Had that kind of damage occurred, it could have taken days, weeks, or even months to restore.. . .This protection (meaning normal operation of relays that shut down the components on the grid) shortened the restoration process considerably."

Advances in Understanding of Space Weather Impacts to Power Systems Over the Past Five Years

There have been significant new findings and ever evolving understanding of the many facets of the complex space weather environment dynamics and the manner in which this impacts the operation of electric power grids. Mitigation of the impacts of these storms will depend heavily on forecast assessments of the onset, severity and regional manifestations of these storms and it is fair to say that much has also been achieved in this regard. While we can be proud of our accomplishments, there remains many unresolved space weather paradoxes of storm evolution and the manner in which they can degrade operations of infrastructures. In particular to the electric power grids, the major achievements can be summarized as follows, with supporting exhibits that elaborate further on many of these main items.

- Integrated and detailed modeling of both complex geomagnetic disturbance environment and complex power grid topologies. These advances have allowed for extensive forensic analysis of historically important geomagnetic storms and their impacts on power grids.
- Improved understanding, as described above, has allowed us to develop much more accurate and detailed quantification of the areas of risk and vulnerability that Space Weather may pose to the U.S. power grid infrastructure. Surprisingly, we are now discovering that risks from storms are not just limited to high latitude located power grids, locations normally associated with auroral observations. New understandings indicate that highly developed power grids at all latitudes may be impacted by various space weather disturbance processes in the U.S. and around the world that were unknown to us just a few years ago.
- These models and environment interaction understandings have also allowed the power industry to understand other aspects of evolving power grid vulnerability to the space weather environment that were not fully understood heretofore. The studies, which are part of the findings from the EMP Commission investigations, indicate that over the past several decades, various design decisions and growth of the power grid infrastructure has caused growing vulnerability to geomagnetic storms. In short, over the past ~50 years, the size of the power grid has grown by nearly tenfold, and has also grown in sophistication such that it now presents a larger, effective antenna to electromagnetically couple with geomagnetic storm disturbances. This has the affect of amplifying storm-caused disturbances in modern power systems. This vulnerability increase is not just limited to improved coupling due to larger grid size but also due to other related infrastructure design decisions, as more fully described in a recent article in Exhibit 9. The industry is also facing growing vulnerability to space weather events due to operational impacts that are occurring from deregulation and transitioning to market-based operation of the power grid. The recent blackout of August 14, 2003 highlighted many of the infrastructure and power market operational concerns. These concerns include continued large growth in electric power demand in the face of diminishing growth in the transmission network infrastructure needed for delivery of power. As a result, power pools such as PJM report for example in year 2000, the pool experienced a total of 3830 hours transmission network constraint operation.[1] In other words, ~44 percent of the year power flows on the transmission system were at or very near maximum levels. These congestion problems only worsened in 2001 as the hours of congestion of the real-time market increased to 4823 hours (~55 percent of the year).[2] This heavy loading is another way of saying that the system is stressed to the safe operating limits and therefore unable to readily counter or safely absorb added stress to these same assets that could occur due to large geomagnetic storms. A recent article, Exhibit 10, provides a more detailed commentary on "What's Wrong with the Electric Grid." While it does not speak to the subject of space weather, it concisely describes the added burdens on today's transmission network infrastructure, the same portion of the infrastructure impacted by space weather events.
- The same efforts to evaluate impacts and risks of today's infrastructures have also allowed us to examine the plausible risks that could result from historically large storms that have not yet been experienced by today's power grid infrastructure. These studies were an especially important focus of the EMP

[1] PJM Interconnection State of the Market Report 2000, June 2001
[2] PJM Interconnection State of the Market Report 2001, June 2002

Commission investigations that have been underway for the past 18 months. The results indicate that major power grid operational impact threats loom due to these low probability, but very large storm events. For instance, we have examined in detail the specifics of the March 1989 super storm and as previously discussed witnessed unprecedented power system impacts for storm intensities that reached levels of approximately 300 to 600 nT/min. However, the investigation of very large storms have made us newly aware that storm intensities over many of these same U.S. regions could be as much as 4 to 10 times larger. This increase in storm intensity causes a nearly proportional increase in resulting stress to power grid operations. These storms also have a footprint that can simultaneously threaten large geographic regions and can therefore plausibly trigger even larger regions of grid collapse than what occurred on August 14, 2003. Exhibit 12 is a brief opinion article that discusses the context of the events leading up to the August 14, 2003 blackout and how such a scenario could in the future be triggered by a space weather storm. Exhibit 13 provides a more detailed summary of investigations undertaken on the U.S. power grid for impacts caused by very large geomagnetic storm events. As shown in this series of studies, disturbance impacts to power grid operations could plausibly be 3 to 10 times larger in the U.S. than those experienced in the March 1989 super storm. This paper shows one of many possible scenarios for how a large storm could unfold. As illustrated in Figure 8, a large region of power system collapse is projected for severe geomagnetic disturbance scenarios. Depending on the morphology of the geomagnetic disturbance, it would be conceivable that a power blackout could readily impact areas and populations larger than those of the recent August 14,2003 blackout.

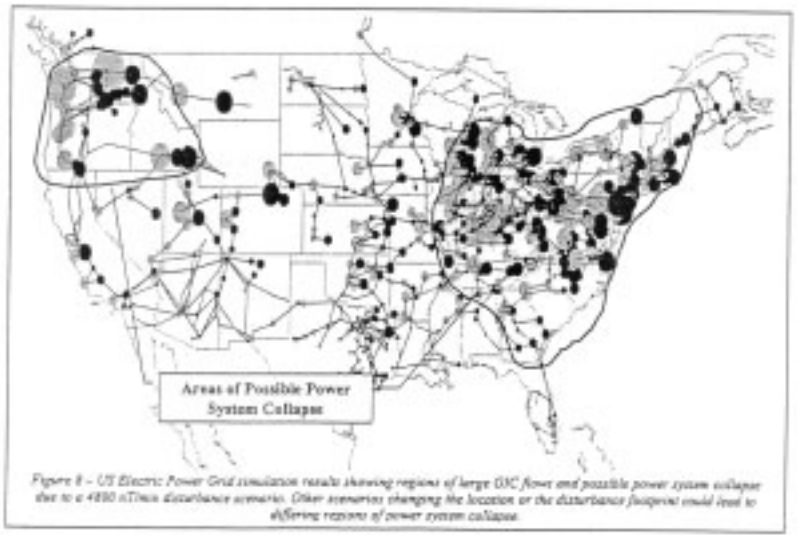


Figure 8 – US Electric Power Grid simulation results showing regions of large GIC flows and possible power system collapse due to a 4800 nT/min disturbance scenario. Other scenarios changing the location or the disturbance footprint could lead to differing regions of power system collapse.

While these complex models have been rigorously tested and validated, this is an exceedingly complex task with uncertainties that can easily be as much as a factor of two. However, just empirical evidence alone suggests that power grids in North America that were challenged to collapse for storms of 400 to 600 nT/min over a decade ago, are not likely to survive the plausible but rare disturbances of 2000 to 5000 nT/min that long-term observational evidence indicates have occurred before and therefore may be likely to occur again.

Because large power system catastrophes due to Space Weather are not a zero probability event and because of the large-scale consequences of a major power grid blackout, I am compelled to, add some commentary on the potential societal and economic impacts of such an event should it ever re-occur. The August 14, 2003 event provides a good case study; the utilities and various municipal organizations should be commended for the rapid and orderly restoration efforts that occurred. However, we should also acknowledge that in many respects this blackout occurred during

highly optimal conditions that were somewhat taken for granted and should not be counted upon in future blackouts. For example, an outage on January 14 rather than August 14 could have meant coincident cold weather conditions. Under these conditions, breakers and equipment at substations and power plants can be enormously more difficult to re-energize when they become cold. This can translate into the possibility of significantly delayed restorations. Geomagnetic storms as previously discussed can also permanently damage key transformers on the grid, which further burdens the restoration process. For that matter, these conditions could rapidly cause serious public health and safety concerns, in that people trapped in regions such as New York City would not have the option of a "Night in Central Park Experience" and perhaps not be able to easily find adequate shelter from the elements. The time of day when the outage occurred was also a significant advantage, in that the bulk of the utility company day crews were still available and able to be readily dispatched to perform restoration functions. In major cities, the blackout essentially brought to a halt most transportation systems. All mass transit systems shutdown as they depend on electricity for many of their functions. Traffic signal systems on most major streets and highways stopped and as a result most major thoroughfares became the equivalent of 8 lane parking lots in the early hours of the blackout. Only a few major power facilities are continuously manned, and since blackouts are possible at any hour, the odds are that ~75 percent of the time the normal utility day crews are not on the job when these events occur. Attempting to recall workers that are trapped on the wrong side of these transportation snares is highly problematic.

In many respects, the loss of power supply returns much of our society to a preindustrial era, because the loss of power supply rapidly cascaded into many other infrastructures. For example, water and sewage plants and transportation systems generally shutdown across the affected regions, even some 911 emergency systems and communication systems were impacted. Power grids are arguably the most important of the critical infrastructures because most of the other critical infrastructures are so highly interdependent on reliable power supply from the grid. It is clearer now that the technology age has increased our reliance on electric power. Figure 9 shows a chart plotting the primary interdependency links that exist between electric power and other critical infrastructures and services such as water, transportation, telecommunications and fuel supplies. As this illustrates, electric power supply is central to the sustained operation of most of the Nation's other critical infrastructures.

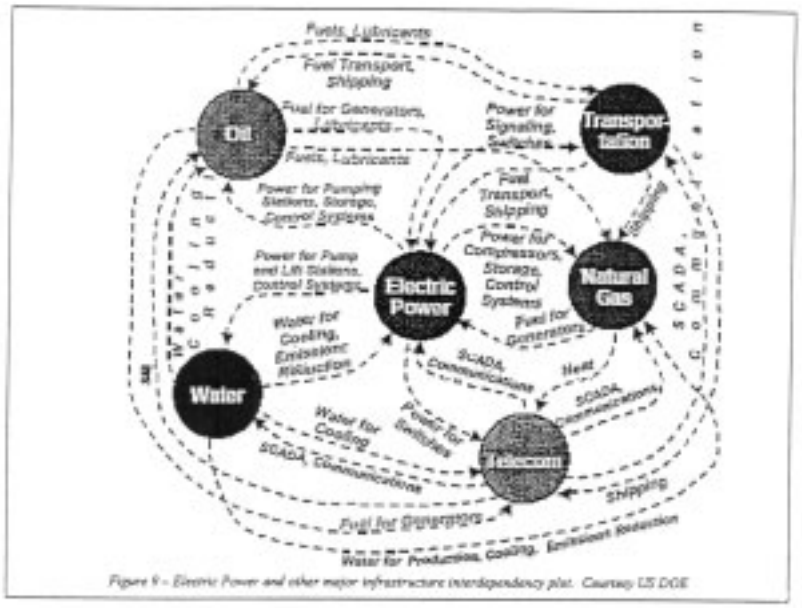


Figure 9 – Electric Power and other major infrastructure interdependency plot. Courtesy US DOE

Only a small portion of these infrastructure facilities have emergency on-site generation of sufficient capacity that allows them to continue operation in the face of a blackout event. Water treatment and pumping require enormous amounts of electric power and as result very few of these systems have redundant power supply options. Loss of pumping in time will lead to drop of city water pressure, as storage tanks and reservoirs cannot be recharged for residential distribution. In large high-rise buildings, city supply water pressure needs to be supplemented with electric pumps to lift water to upper floors for water distribution. Therefore within a matter of a few hours potable water distribution in many locations can become a serious concern. Perishable foods are generally at risk of complete loss within 12 hours or less. As previously discussed, transportation of all types was seriously impacted. Even automobiles and trucks could only operate within the range of the fuel in their tank at the time, because nearly all refueling operations from underground storage tanks require restoration of electric power supply.

Most affected regions were restored within approximately 24–36 hours after the blackout. As described in hearings on October 20 before the House Financial and Banking Infrastructure Committee, the major telecommunications (not counting wireless-cellular phone systems) and interdependent financial systems were able to maintain many functions. However, this was due to backup generation at a few critical hubs, which generally have around 72 hours of available fuel. Therefore power grid outages of longer durations would be highly problematic in that refueling may be logistically impossible in all situations. W.A. Abernathy, the Assistant Secretary for Financial Institutions, cautioned in his testimony that our financial institutions primarily operate on the principle of confidence, *"confidence that financial transactions will be carried out, that checks will clear, that bills will be paid, that investments will be made, that insurance promises will be kept. The confidence provided by financial institutions and their services play a big part in helping to cope with the trauma of disaster."* An event which causes the eventual cessation of these functions, even for a short time, in key financial centers could have potential for wide spread consequences to the economy.

Because of the possible large geographic laydown of a severe storm event and resulting power grid collapse, the ability to provide meaningful emergency aid and response to an impacted population that may be in excess of 100 million people will be a difficult challenge. Potable water and replenishment of foods may need to come from boundary regions that are unaffected and these unaffected regions could be very remote to portions of the impacted U.S. population centers. As previously suggested adverse terrestrial weather conditions could cause further complications in restoration and re-supply logistics.

Space Weather and Power System Understandings—The Future

Given the surprising and potentially enormous implications of recent power system threats due to space weather, it is difficult to accurately predict what the future may bring. However, the future of space weather is being shaped, in fact, by activities that are underway today. Much good work is underway to continue efforts such as described here to further understand and evaluate the potential impacts of large storm events. While having the ability to accurately assess threats to these infrastructures is an important accomplishment, the real payoff of this capability is in the application of this knowledge towards engineering solutions that reduce the risks. In order to protect against the effects from severe geomagnetic storms, several approaches may need to be used. In terms of the entire grid itself, remedial measures to reduce GIC levels may be needed, such as installation of supplemental transformer neutral ground resistors to reduce GIC flows and undo this unintended geomagnetic antenna that has developed as the industry has built the present day high voltage transmission grid in the U.S. Grid operational measures can be better evaluated and tested for the multitude of scenarios and procedures enhanced to prevent severe voltage regulation problems in order to preserve the integrity of the network as a whole. This means that additional generation capacity and fast acting voltage compensating reserves should be available and/or loads should be rapidly removed from the system. This requires advanced information and contingency planning by the power utilities. With the aid of continuous solar wind monitoring, it is possible to reliably predict the onset of a storm 30 to 45 minutes in advance. This is due to the availability of real-time satellite data and modeling capabilities that are now within the state-of-the-art. These capabilities are reasonably expected to further improve within the next five years, but only as long as the Nation maintains a commitment to gather the observational data and disseminate it for the forecast models that can use it.

Question 4. What would be the impact to your organization and the electric power grid industry if the SEC were no longer able to provide its space weather forecasts to you? Please provide specific examples when possible.

In response to this question, let me first speak to the impacts upon the power industry should the SEC or the Nation's space weather forecast capability cease to exist. As previously discussed, the power industry has been aware of the potential for some large impacts due to storms and as recent discoveries indicate, these threats have the potential to be even more ominous in their implications that previously understood. It is also clear that the vulnerability that presently exists has evolved due to long-term trends and that these trends because they involve embedded designs to billions of dollars in assets cannot be undone overnight. The most effective mitigation strategy in the short-term and perhaps in the long-term is improved situational awareness for operators of these systems from evolving space weather disturbances and then attempting to counter some of the impacts by providing more robust operational postures in anticipation of storm-caused impacts.

In the era prior to solar wind monitoring and the advances in improved solar activity monitoring, storm events would often blindside operators with sudden onsets. Unlike most terrestrial weather, these events develop suddenly once the threatening inputs from solar activity arrive at the Earth. The loss of these capabilities would return us to the 1980's, where all that existed in many respects was a monitoring service and storm information for the most part arrived *after-the-fact* and therefore could not be usefully utilized to avoid significant operational impacts, rather the information just confirmed for operators what caused any impacts and only marginally better prepared them for additional impacts from the same storm. Therefore, power grids would have to rely almost exclusively on their own power grid monitors for the first signs of possible storm impacts. However, these would be a poor substitute in most respects and would create a number of operator uncertainties and paradoxes. The operators would not be able to receive advance notice of severe impacts that appear with sudden onsets. For storm events that have slower evolution, it would take some time to determine if operating anomalies are due to a geomagnetic storm or some other event. Once they determine that it is a geomagnetic storm then it would be necessary to be overly cautious and restrictive for many additional hours of small storm activity because it would be difficult to know if a larger storm development is possible. In the aftermath of the Hydro-Quebec collapse, the operators of that system based operational procedures on observations of local activity. In 1991, they spent nearly 10 percent of the year in geomagnetic storm operating posture and as a result reduced substantially their ability to transfer large blocks of power across their network and export it outside their system. In today's more volatile electric energy markets, such operating postures could produce substantial added hours of constricted operation of networks and have immediate cost impacts on real-time electric energy markets. An example of this type of energy market cost impact can be illustrated by a storm on July 15, 2000 and the response of the power, market when the PJM power pool declared a storm emergency. On July 15, 2000, the PJM declared an SMD emergency beginning at 15:30 and declared an end to the SMD emergency at time 21:07, resulting in a period of ~6 hours of emergency conditions in which PJM follows prescribed procedures for network conservative operation as described in Sections 3–1 to 3–5 of the PJM Operations Manual. During this ~6 hour period, the real-time price increased approximately $40/MWH on average. Under conservative operation, the operation of the power network biases towards security and reliability of the network as a whole rather than just economic dispatch. As a result, transfers across the network can be significantly reduced, leading to re-dispatch of generation and cost increases in the real-time market due to less optimal economics in the dispatch of generation in this security mode of operation. Even though this storm event occurred under light load and highly favorable market conditions, the cumulative real-time market cost increase totaled ~$900,000. Storm assessment uncertainties can extend longer than necessary operation of the network in these restricted market conditions and add even more to these cost impacts. During some periods of the day, energy cost increases can be much more severe and total costs could be even higher as a result. Of course, the economic and societal costs of large scale failures in the U.S. power grid overwhelm all other cost concerns and forecast efforts provided to prevent that scenario from being realized should be of paramount concern.

Metatech is dependent for many of the forecast products we supply upon reliable, high-cadence and high quality data from the SEC as needed inputs into the models and forecast systems we operate. In response to cessation of the SEC functions, we would have to significantly alter and as a result diminish the quality of some of the services we could provide. In addition, I would suspect that some commercial pro-

viders may choose to simply exit the business in response and others that might have been willing to enter the business will instead decide not to do so. Further, it would be unlikely at this time that any commercial provider would decide to enter the market to shoulder the heavy burden of launching satellites and setting up and coordinating various world observatories needed to provide important data inputs. In short, the customers, no matter who the provider, would have fewer options available to them and would receive an overall lower quality of service. Lacking any official government agency responsible for space weather forecasting, a likely development at times will be the equivalent of a "Tower of Babel," where information is widely scattered amongst a large number of government, military, and international observation sites and each speaking in a differing tongue as to their interpretation and not one of them having complete enough information to develop a useful "Big Picture" of the unfolding space weather events.

Even the idea of a successor agency being handed the responsibility that currently resides with the SEC has a number of potential impact consequences. No matter how dedicated the new responsible agency, there will be unavoidable losses in the transition. Any new organization would need to successfully overcome the added start-up hurdles before even considering how best to meet the challenges of forecasting a difficult space weather environment. Since our company has commercial responsibilities similar to the associated activities that the SEC must perform to deliver their products, I can certainly state that an operation such as this has many high maintenance and expensive tasks. This includes such unglamorous but vital back office and field tasks such as data collection, quality control of the data and, finally, timely data dissemination. These all need the continuity of an experienced and capable staff of unsung heroes to assure the high level of reliability and availability that has been provided by the SEC. These systems, of course, need to work in harmony with the derived products and forecast services that are the more familiar face of the SEC. As I have emphasized previously in my testimony, the space weather disturbances we are attempting to forecast can have amazingly rapid onsets and can manifest as a diverse variety of consequences to large geographic regions. Therefore forecast staff needs to be highly trained and experienced so they can quickly assess and judge, as there is no time for hesitancy and uncertainty. Further all this needs to be done on a continuous 24 hour by 7-day per week basis, as the Sun never sets on the Nation's threats from Space Weather disturbances. As you can surmise, setting up a new function such as this is not a matter of buying a few servers, installing some shrink-wrap, and parking some people in front of a monitor. Nearly every function that is done involves much in the way of custom systems and a high degree of specialized human "know how." Therefore the loss of the highly trained and experienced staff would be an unfortunate loss of investment by the Nation and setback our collective capabilities in space weather forecasting.

In conclusion I would also like to offer a perspective on the long-term needs that should further be considered by this committee in supporting our nation's efforts to better mitigate concerns arising from space weather events. For example, the degree of deterioration in the reliability of the electric power grid has been a topic of considerable discussion, post August 14, 2003. It is now evident that uncertainty in long-term restructuring, and lack of transmission infrastructure investment were significant factors contributing to the events of that day. Yet no matter how maligned, this infrastructure is still capable of operating through "single-point" failures. In contrast, our nation's most important space weather monitoring assets have no redundancy in case of failure. A loss, for example, of the NASA–ACE solar wind monitoring satellite (at the vital L1 position in space) would largely deprive the Nation of the ability to perform high quality short-term forecasting of geomagnetic storms. The end of lifetime for ACE is rapidly approaching and still no formal plans exist by any government agency in the world for a replacement satellite. Other examples also exist for various other observation assets that supply needed data inputs to our space weather forecast systems. Our grasp on the ability to perform these vital functions can be lost at any moment in time and we may not be able to recover for a number of years in some cases. Therefore I would also like to urge the Committee to consider these future "heavy lifting" responsibilities in sustaining and improving our nation's space weather infrastructure, once we get past this current SEC funding crisis.

Chairman EHLERS. Thank you very much.

Next, Captain Krakowski.

STATEMENT OF CAPTAIN HENRY P. (HANK) KRAKOWSKI, VICE PRESIDENT OF CORPORATE SAFETY, QUALITY ASSURANCE, AND SECURITY, UNITED AIRLINES

Captain KRAKOWSKI. Chairman Ehlers, Ranking Member Udall, and Members of the Committee, on behalf of United Airlines, we would like to thank you for the opportunity to submit testimony with the direct bearing on flight safety, public health, and commercial efficiency. In addition to my 25 years as a United Airlines pilot, I am also responsible for safety, security, and operational quality at our company.

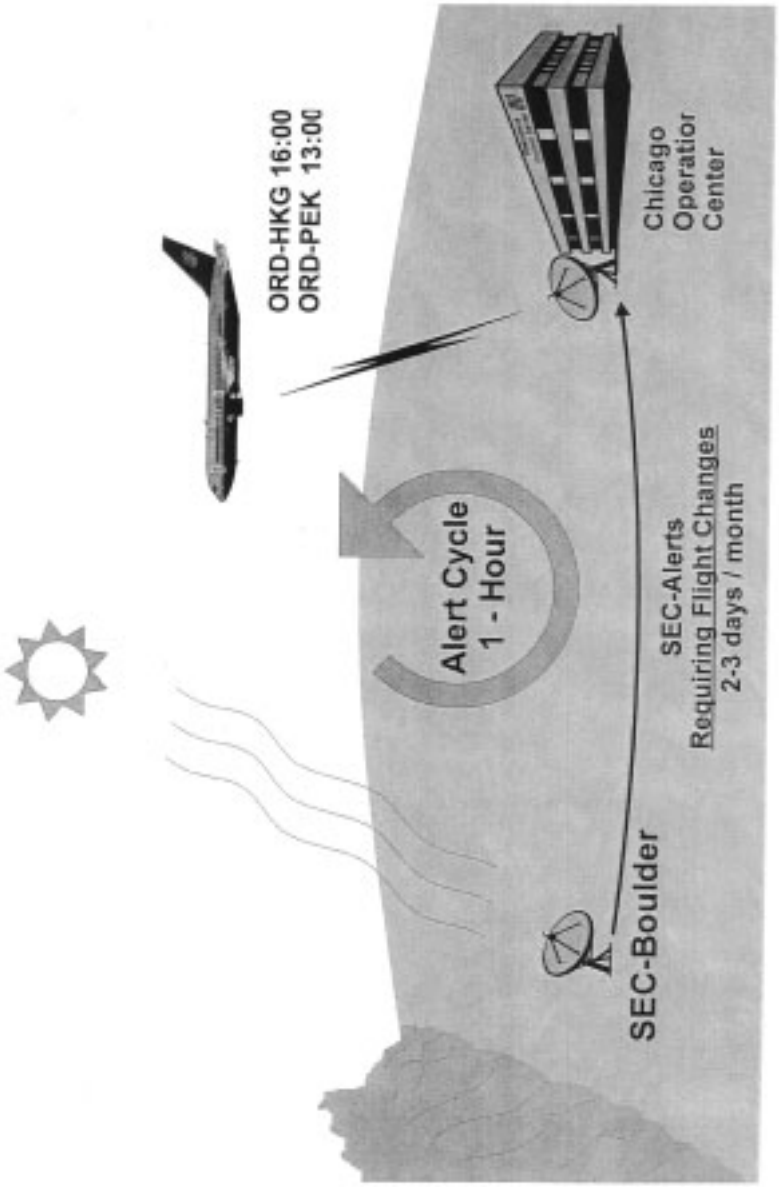
Mr. Chairman, if you flew from Grand Rapids, Michigan to Beijing or Hong Kong six years ago, it would have taken nearly a day, connecting over at least two cities. Today, through the pioneering efforts of United Airlines in cooperation with other agencies and countries, we can now fly from Grand Rapids to these and other Asian cities in just 16 hours with one flow through Chicago. This is possible because of our ability to fly over the North Pole, Russia, and China. In fact, State Department officials involved in recent talks in China enjoyed the convenience and efficiencies of these very flights.

Safety is always our number one priority at United Airlines. Toward that end, while polar routing provides a tremendous advantage of time and convenience for our customers, everyone on these flights could be exposed to potential safety risks that did not exist when flying at the lower latitudes. Information we receive from the Space Environment Center operated by NOAA ensures that United Airlines can take timely action to mitigate the risks associated with an occasional solar activity, which can disrupt communication, navigation, and even impact crew member and customer health.

During such a solar activity, our company policy dictates that United restricts flights from certain routes and altitudes. If we are made aware of a threatening activity prior to a flight, United will not hesitate to fly at lower altitudes or latitudes or even incur a costly fuel stop in Japan or China.

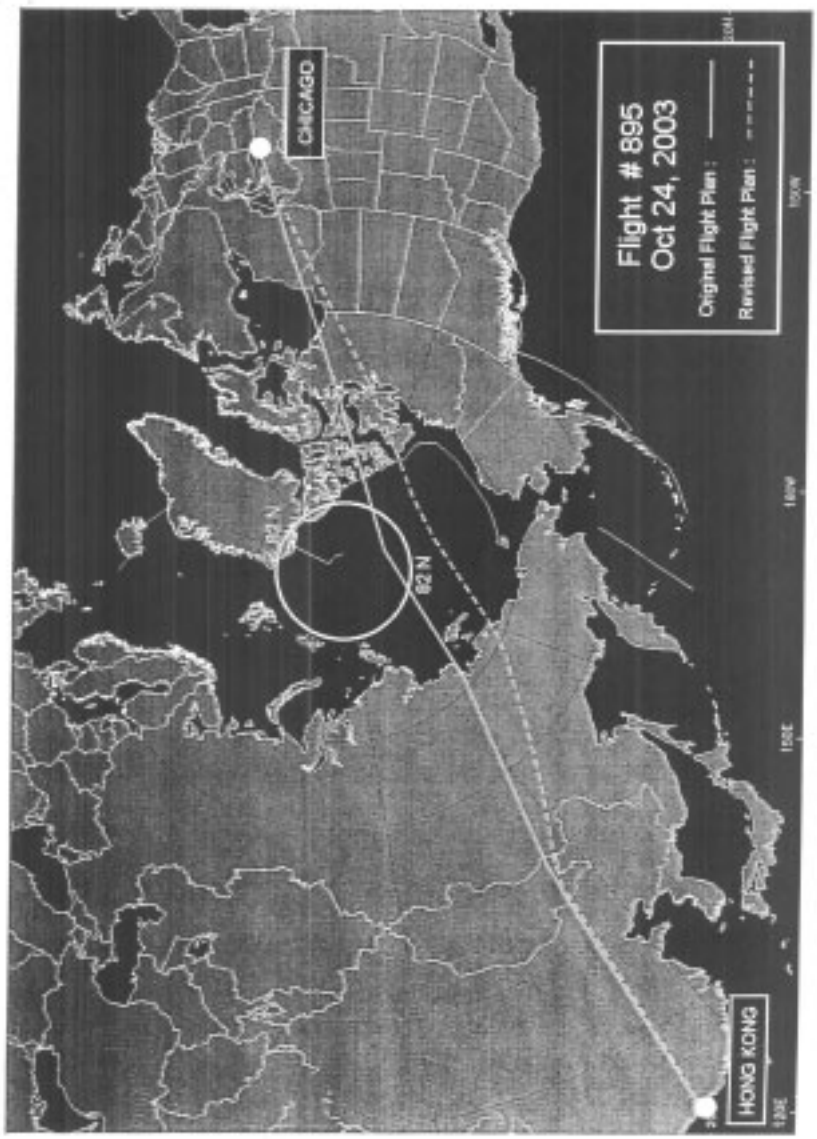
United is one of the few airlines which maintains an in-house meteorology department that works with our dispatchers and our flight crews to provide a safe, comfortable flight. We are proud of our excellent reputation in forecasting safety threats.

The solar environment, however, is so unique that it requires specially trained forecasters and specific technology not available within the commercial sector. The SEC is our only link to that environment.



As this chart depicts, we blend the information from SEC right into our flight planning process on both a daily and hourly basis. The SEC provides United with daily forecasting, monitoring, and, most importantly, immediate alerts, some of which can affect flight operations in as short as 10 minutes. We can demonstrate that the current process works exceedingly well.

In our five years of flying over the North Pole, United has found the need to alter flight plans on an average of two to three times per month. In some cases, when the event is severe, as we have recently experienced, we will alter flights sometimes already in the air.



The current chart depicts an event which occurred on October 24, our flight 895 between Chicago and Hong Kong, was planning to fly the polar route. We replanned the route away from the North Pole due to an R3 solar event. This routing took an additional 30

minutes of time. We had to burn 3,000 extra gallons of gas, and it cost United Airlines $10,000 to operate—more to operate that given flight. We do this regularly, if needed.

Mr. Chairman, United works with numerous government agencies from the FAA to the TSA. NOAA and the SEC distinguish themselves, in our opinion, by being an exceptionally transparent and customer-oriented partner with the airlines. I have personally visited the SEC in Boulder and can attest to the talent and professionalism of their staff. We are concerned that a reduction in funding could damage this important source of real-time safety information for our company. We also are concerned that transferring the operation to another federal agency could cause a disruption, degradation, or even filtering of information.

We urge you to support this program and seriously consider the ramifications associated with the change of oversight. We operate polar flights every day. A degradation of performance of this entity would cause us to become overly conservative in our flight planning, which would be costly. In our view, this is a program not in need of a fix. In our view, it is actually a program of American tax dollars at its best for the protection of United States citizens.

Again, thank you for allowing me to testify, and I do look forward to any questions you may have.

[The prepared statement of Captain Krakowski follows:]

PREPARED STATEMENT OF CAPTAIN HENRY P. (HANK) KRAKOWSKI

Chairman Ehlers, Ranking Member Udall and Members of the Committee, on behalf of United Airlines, thank you for the opportunity to submit testimony concerning a subject that has direct bearing on flight safety, public health and commercial efficiency. In addition to my 25 years as a United pilot, I am also responsible for Safety, Security and Operational Quality at our company.

Mr. Chairman, if you flew from a city such as Grand Rapids, Michigan to Hong Kong or Beijing six years ago, the journey would connect through at least two cities and take nearly a full day to complete. Today, through the pioneering efforts of United Airlines in cooperation with multiple countries and agencies, one can fly from Grand Rapids to these and other Asian cities in just 16 hours with only one connection over Chicago. This is possible by flying directly over the North Pole, Russia and China. In fact, State Department officials involved in recent talks with China enjoyed the convenience and efficiency of these very flights on United between Chicago and Beijing.

Safety is always our number one priority at United Airlines. Toward that end, while polar routing provides a tremendous advantage of time and convenience to our customers, everyone on these flights could be exposed to potential safety risks that did not exist when flying at lower latitudes. Information we receive from the Space Environment Center (SEC), operated by the National Oceanic Atmospheric Administration (NOAA), ensures that United Airlines can take timely action to mitigate any risks associated with occasional solar storm activity that can disrupt communication, navigation and impact passenger and crew member health.

During such solar activity, our company policy dictates that United restrict flights from certain routes and altitudes. If we are made aware of threatening activity prior to the flight, United will not hesitate to fly at lower altitudes and latitudes or incur a very costly fuel stop.

United is one of the few airlines that maintain an in-house meteorology department that works with our dispatchers and crews to provide a safer and more comfortable flight. We are proud of our excellent reputation in forecasting flight safety threats.

The solar environment, however, is so unique that it requires specially trained forecasters and specific technology not available within the commercial sector. The Space Environment Center the only link to this environment. We blend the information received from the SEC into the flight planning process daily and even hourly. The SEC provides United with daily forecasting, monitoring and, most important,

immediate alerts some of which can affect flight operations in as little as 10 minutes. We can demonstrate that this process works exceedingly well.

In our five years of polar flying experience, United has found the need to alter flight plans two or three times per month. In some cases, when an event is severe, we will alter flights already in the air.

Please take a look at the chart that we have provided for the Committee's reference. As recently as last week, on October 24th, United flight 895 from Chicago to Hong Kong planned to fly a polar route. The flight was re-planned, however, on a more southerly route due to a R3 magnitude solar event. This routing took 30 extra minutes and used 3,000 gallons of extra fuel for a total added cost to the company of $10,000 for that flight.

Mr. Chairman, United works with numerous government agencies from the FAA to the TSA. NOAA and the Space Environment Center distinguish themselves by being an exceptionally transparent, customer-oriented partner with the airlines. I have personally visited the SEC in Boulder and can attest to the talent and professionalism of this organization and their people. We are concerned that a reduction

in funding could damage this important source of real-time safety information for our airline. We are also concerned that transferring operation of the SEC to another federal agency could result in a disruption, degradation or filtering of critical information.

We urge you to support this program and seriously consider the ramifications associated with a change in program oversight. We operate polar flights each and every day. A degradation of performance in this program would cause us to become overly conservative in our flight planning. In our view, this program is not an example of a government program that is broken and in search of a fix. Quite to the contrary, our work in cooperation with the SEC exemplifies the use of American tax dollars at its best for the protection of U.S. citizens.

Again, thank you for allowing me to testify before the Committee. I look forward to any questions you may have.

Chairman EHLERS. Well, as one would—might expect from a pilot, you are finished with two seconds to spare, so your ETA calculation was very good.

Dr. Hedinger.

STATEMENT OF DR. ROBERT A. HEDINGER, EXECUTIVE VICE PRESIDENT, LORAL SKYNET, LORAL SPACE AND COMMUNICATIONS LTD.

Dr. HEDINGER. Thank you, Mr. Chairman.

My name is Robert Hedinger. I am an executive vice president with Loral Skynet, a communications satellite service provider, and also a division of Loral Space and Communications. I am pleased to appear before your Subcommittee to discuss the effects of space weather on communication satellites and the vital role played by NOAA's Space Environment Center.

I would also like to mention that the Satellite Industry Association has also developed a record for this committee, which I would like to attach to our record, as well.

Chairman EHLERS. Without objection, so ordered.

Dr. HEDINGER. Okay. Thank you.

I would like to provide the Subcommittee with some background on the economic importance of the U.S. satellite industry and then address specific questions included in your letter of invitation. Additional supporting material has been provided in the attachments to my record.

Let me begin by pointing out the significant commercial investment and critical telecommunication services that are at risk resulting from space weather effects. As the attached charts in the record will demonstrate, $49.8 billion of revenue was generated and $12.1 billion of investments were made in 2002 in this industry. And these figures are expected to grow over the next 10 years. Critical commercial satellite applications that are provided on this infrastructure include: direct to home entertainment video and audio services, nationwide services; broadcast and cable television, all of the networks have satellite distribution networks; radio and audio distribution; satellite news gathering; the collection of critical news events from events that are occurring across the country; paging services; location and tracking services; rural and remote access services for telephony, data, and Internet; critical services for remote education and telemedicine; data communications to hundreds of thousands of locations used by the retail industry for such applications as point of sale terminals, credit card processing, and inventory tracking.

I would now like to address, in more detail, the questions that you had addressed in your invitation.

The first question: "How does space weather affect satellite communications?" Temporary and/or permanent damage to on-board equipment resulting from electrostatic discharges, the space—the surface of the spacecraft can be charged with the large amounts of charged particles in the environment and then discharged, causing an electrical spark, which can damage equipment. Performance degradations and service outages due to particle events, in particular, electrical sensors, which are used for maintaining pointing accuracy of the spacecraft, can be—can experience a similar effect to fog as a result of having high-energy particles around the sensors. Altitude control and pointing errors due to magnetic field variations. Certain spacecraft rely on a strong magnetic field to target the spacecraft to keep it aligned. When a geomagnetic storm occurs, the magnetic field fluctuates and sometimes can become quite weak and not be strong enough to drive the momentum of the spacecraft. So these are some of the major impacts that space weather has on the satellites.

The next question is: "How do satellite operators use the data that is provided by NOAA?" I see I am running short on time. I would love to go through a long list. There is a lot of this information in the document, but to cut it short, we can prepare ourselves for a lot of events that could be detrimental to the spacecraft ahead of time. We take precautionary measures. We may set up a reconfiguration of the spacecraft that, instead of having automated commands, we send manual commands to the spacecraft. Because of the environmental changes that take place, they could mask some true events that are occurring and cause satellites to go into a mode which is undesirable.

The third question you asked was: "What has happened in the last five years? What do we expect in the next five years?" Over the last five years, we have certainly gotten more data, but more importantly, we have had access to that data in a much more rapid and user-friendly environment as a result of the NOAA SEC approach to distributing this information to the commercial satellite industry. The next five years, we know that there is continuing research that needs to be done. In specific—specifically, we would love to have additional forecasts that can be specific about orbital locations and the impacts on very specific satellites.

The fourth question: "What would we do without it?" We couldn't live without this data. We need this data. It is absolutely critical for our operations.

In summary, Mr. Chairman, the functions that NOAA SEC performs to model, predict, and send out alerts on space weather has been, and continues to be, critical to commercial satellite operators. NOAA SEC has provided excellent service to communication satellite operators. It is critical to the commercial satellite industry that NOAA SEC continue providing these services without disruption.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Hedinger follows:]

PREPARED STATEMENT OF ROBERT A. HEDINGER

Mr. Chairman and Members of the Subcommittee, my name is Robert Hedinger, I am an Executive Vice President with Loral Skynet, a communications satellite service provider, and a division Loral Space and Communications Ltd. I am pleased to appear before your Subcommittee to discuss the effects of space weather on communications satellites and the vital role played by NOAA's Space Environment Center.

I would like to provide the Subcommittee with some background on the economic importance of the U.S. satellite industry and then address the specific questions included in your letter of invitation. Additional supporting material has been provided in the three attachments.

Let me begin by pointing out that significant commercial investment and critical telecommunications services are at risk resulting from space weather effects. As the attached charts in Appendix A demonstrate, $49.8 billion of revenue was generated and $12.1 billion of investments were made in 2002 in this industry and these figures are expected to grow in the next ten years.

Critical Commercial Satellite Applications include;

- Direct to Home Entertainment Video and Audio Services
- Broadcast and Cable TV
- Radio and Audio Distribution
- Satellite News Gathering
- Paging Services
- Location and Tracking Services
- Rural and Remote Access Service for Telephone, Data and Internet
- Critical Services for Remote Education and Telemedicine
- Data communications to hundreds of thousands of locations used by the retail industry for such applications as point of sale terminals (credit card processing) and inventory tracking.

Answers to Questions Asked in the Letter of Invitation

To address your first question, space weather can affect satellite operations in the following ways:

- Temporary and/or permanent damage to on-board equipment resulting from electrostatic discharges
- Performance degradations and services outages due to particle events
- Attitude control and pointing errors due to magnetic field variations

Additional information and examples are provided in Appendix B.

To address your second question, satellite operators use data and products from NOAA's Space Environment Center (SEC) in the following ways:

- By being prepared, the Satellite Control Centers (SCC) operated by Loral and other service providers can reduce the amount of service outage time by focusing on the corrective action more quickly (avoiding some of the initial troubleshooting).
- By communicating these events to our customers, Loral can provide them the ability to plan around potential problems.
- By activity scheduling, Satellite Control Centers can avoid sensitive maneuvers and housekeeping functions during peak storm activity.
- In some instances, SEC data is used in real-time to determine the cause of observed anomalies. Using the SEC data the SCC is able to determine if a reconfiguration of the spacecraft is warranted, or if the storm is small enough that we can maintain the current configurations.
- As part of the due diligence that is performed after every spacecraft anomaly, the SEC data is also analyzed. This is done to see if there is a link between the solar environment and the anomalous condition.
- Loral also uses the archive data from the SEC during the spacecraft design and analysis activities.

Additional information and examples are provided in the Appendix B.

To address your third question, five years ago there was less information available and the data format was difficult to work with (fax, paper copies, etc). This has improved significantly over the last five years to allow better access to the available

information. Data is now available online and viewable at an individual engineers terminal.

In the next five years we expect to see a more reliable early warning system, a continuing improvement in the knowledge of the space environment through improved detectors and analysis tools for better spacecraft designs, and improvements in dynamic modeling for specific orbit locations.

Additional information is provided in Appendix B

To address your fourth question, the impacts to Loral and other commercial satellite operators of not being able to access the SEC services would be severe. Without the SEC information, satellite operators would not be able to cancel maneuvers based on solar environment levels and consequently we would not be able to avoid potential damage to the spacecraft. Service outages would also occur more often and be longer in duration. Spacecraft design quality would be compromised without access to current and accurate Space Weather Data.

In summary:

- The functions that NOAA SEC performs to model, predict, and send out alerts on space weather has been and continues to be critical to Commercial Satellite Operators.
- NOAA SEC has provided excellent services to Commercial Satellite Operators.
- It is critical to the Commercial Satellite Industry for NOAA SEC to continue providing these services without disruption.

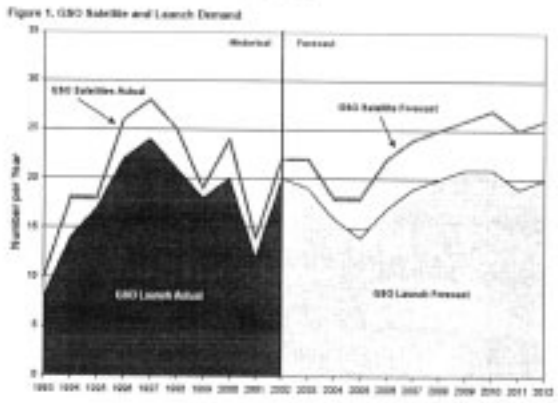
APPENDIX A

Commercial Investments and Critical Services Impacted by Space Weather

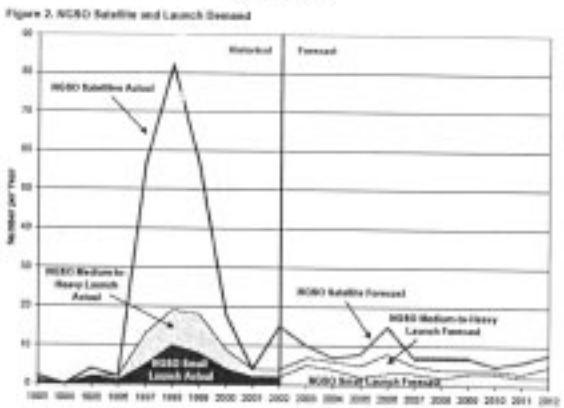
October 30, 2003

233 GSO and 80 non-GSO satellites are expected to be launched between 2003 and 2012

GSO

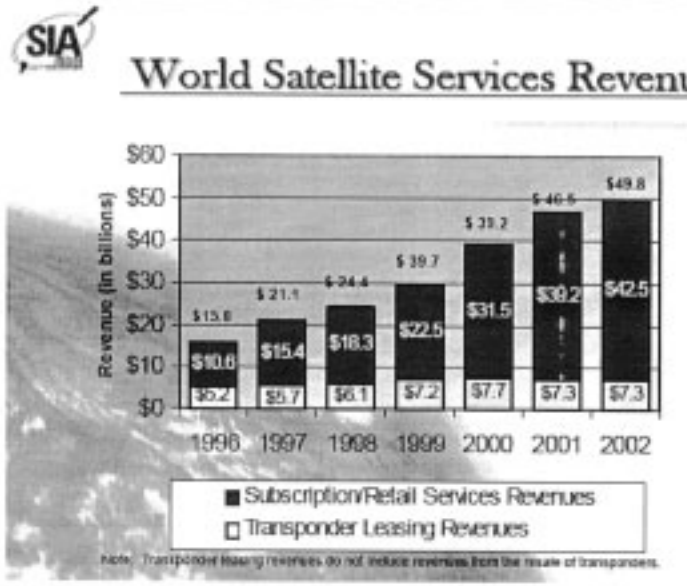


NGSO



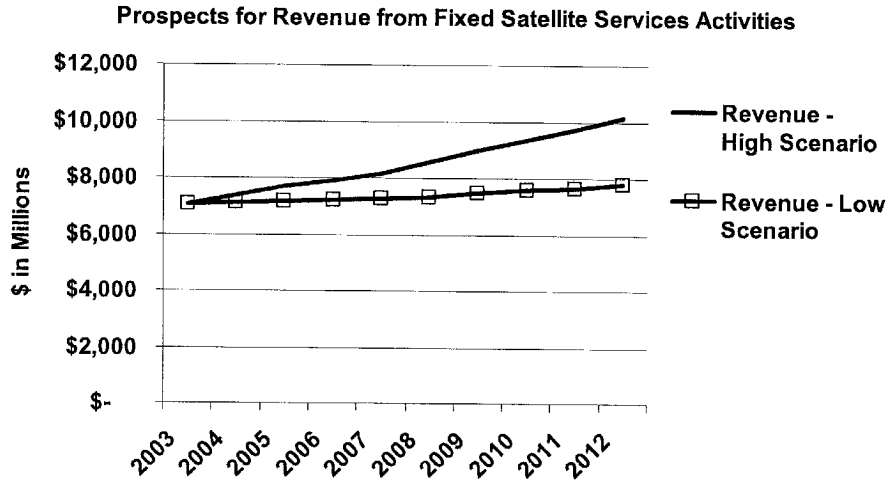
Source: Federal Aviation Administration and the Commercial Space Transportation Advisory Committee (COMSTAC), May 2003

$49.8 billion of revenue was generated in 2002.



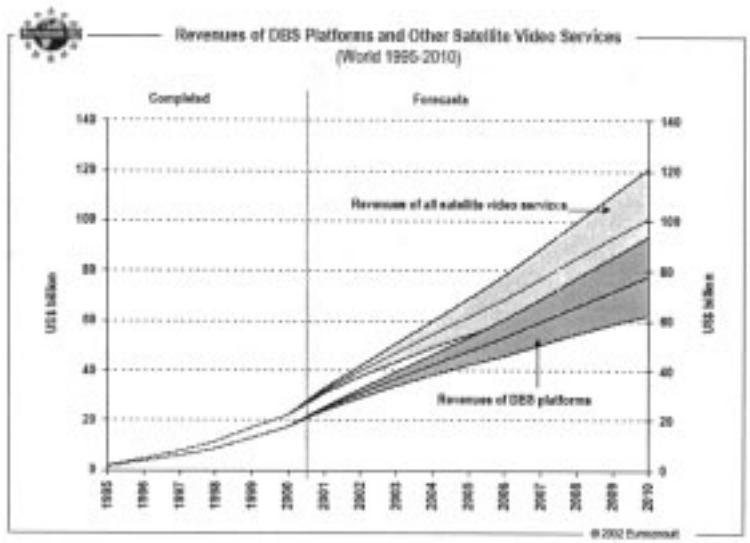
Source: *Satellite Industry Statistics Satellite Industry Statistics*, Prepared by Futron Corporation 2002 2002, Sponsored by the Satellite Industry Association

The transponder leasing revenues portion alone is projected to grow to $10.1 billion per year by 2012;



Data Source: Euroconsult, World Satellite Communications & Broadcasting Markets Survey, 2003 Edition

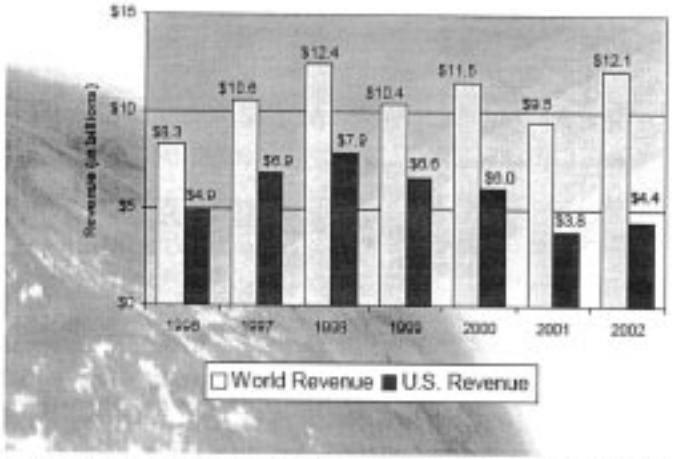
while subscription/retail services revenues could triple between 2003 and 2010



Source: Euroconsult, *Satellite TV & Video Services*, September 2002

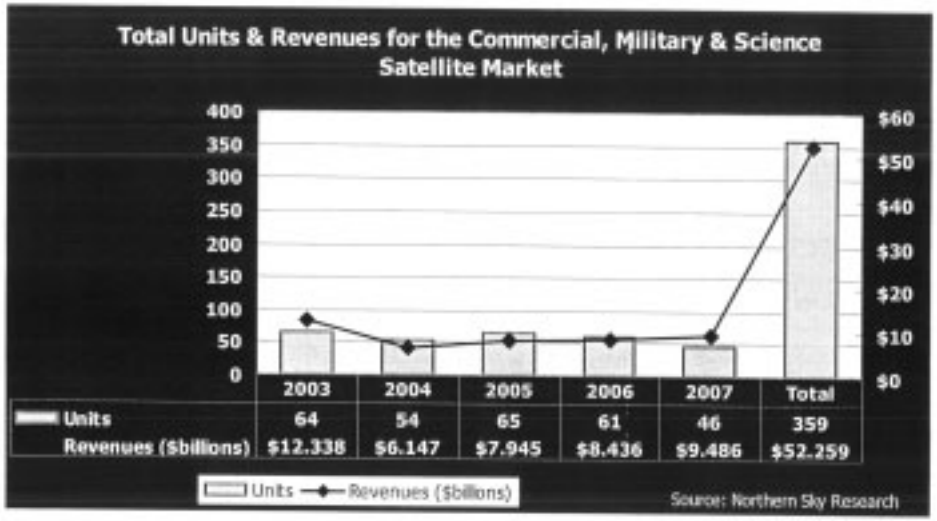
$12.1 billion of investments were made in 2002.

Satellite Manufacturing Revenues



Source: *Satellite Industry Statistics Satellite Industry Statistics*, Prepared by Futron Corporation 2002, Sponsored by the Satellite Industry Association

When military and science satellites are included, satellite investment from 2003 to 2007 could total as much as $52.3 billion.



Source: Northern Sky Research, *Global Demand for Satellite Systems in the Commercial, Military & Science Sectors*, September 2003

APPENDIX B

Answers to Specific Questions Concerning Space Weather

Question 1

Please provide an overview of how space weather can affect satellite operations, including examples of historical events that have caused problems.

Charging Effects

Space weather affects the way the spacecraft body (or internal components) is charged. The spacecraft can only hold so much charge before it reaches a threshold for discharge. During extreme charging environments, this discharge occurs spontaneously and it is called an Electro Static Discharge (ESD) event. As an ESD event potentially contains a large amount of energy, it can be very hazardous to the spacecraft.

Spacecrafts have had major component failures that have been directly related to specific ESD events. On some spacecraft, several ESD events of the same type have occurred. These events have gradually weakened circuitry leading eventually to equipment failure. In addition, ESD events have lead to temporary upset of the spacecraft configuration. All of these events have led to customer outages until the operators have had time to reset the operational configuration using redundant equipment. Imagine if such an event happens during the Super Bowl or World Series. Until a switch over to a redundant transmission path happens, it can affect the TV Broadcasters by causing millions of dollars lost in advertising revenue and a set tens of millions of viewers.

Loral has experienced ESD events on several of their own spacecraft as well as spacecraft supplied to customers. Critical pieces of equipment have been lost due directly to ESD events including momentum wheels, and heaters/thermisters. We have had power equipment, earth sensors, payload units and telemetry and command equipment change operational state. We have had an accumulation of ESD events causing failure of solar array circuits. All of these events have the potential of temporarily or permanently reducing commercial communication or weather service to customers.

Immediate Particle Events

Sudden increase of protons and electrons caused by a storm can cause immediate problems that are not related to charging. The biggest concern here is in partially blinding sensor equipment. On most commercial spacecraft this problem is limited to the instrumentation responsible for determining pointing (earth sensors, star sensors, etc). During a big storm, these sensors do not operate to their full efficiency as they are partially blinded by much noise. Loral has seen attitude control system trips due to this type of particle induced noise. These trips normally result in loss of pointing control (or reduced pointing control) in at least one axis. If the error grows beyond our tolerance, service is affected.

Magnetic Events

Some spacecraft use the Earth's magnetic field for control of pointing. These spacecraft have electro-magnets on board. These magnets interact with the Earth's magnetic field putting a torque on the spacecraft. The magnets on the spacecraft are activated as needed to control pointing. During solar storms that affect Earth's magnetic field, these spacecraft often have trouble maintaining pointing control. Without a strong magnetic field for the magnets to interact with, their efficiency is reduced greatly. During these times it is required to change the spacecraft's actuators from magnetics to thrusters in order to maintain service.

Question 2

How does your organization use data and products from NOAA's Space Environment Center (SEC)? In general, how much lead time do you need to make decisions for mitigating the effects of space weather?

Preparatory

In a perfect world, one week lead time would be desirable. If we had forecast data for the next week, this could be worked into our weekly activity plan. As this is not currently available, we utilize the data as it is available. Some of the warnings for the smaller storms only provide a few hours of notice. These we use in a real time manner when executing activities. Warnings for potentially large storm normally

give a day or two to prepare. As these are the potentially more devastating storms, Loral uses this information as described in the following three sections.

Internal Advisements

Due to increased problems during solar storms as well as the potential necessity to run specialized procedures, Loral utilizes the SEC warnings to prepare. When a warning comes out that meets Loral's criteria for potential problems, internal advisements are issued. These advisements serve to prepare the Satellite Control Centers for any of these potential non-standard operations. By being prepared, the Satellite Control Centers can reduce the amount of service outage time by focusing on the corrective action more quickly (avoiding some of the initial troubleshooting).

The SEC site is monitored in real time 24×7. As events such as earth sensor glitches or attitude error hold off are encountered, the controllers in Loral's Satellite Control Center perform analysis to determine the next step. This analysis utilizes both spacecraft telemetry as well as the real time data from the SEC site. It is important to understand the current state of the spacecraft as well as the expected growth (or diminish) of the storm's strength before taking action.

External Communications

Loral performs external communications to its customers (called a code Orange) when space weather predicts reach predetermined values. This allows our customers to plan for potential spacecraft problems. By communicating these events to our customers, Loral provides them the ability to plan around potential problems. This provides them the ability to increase their service reliability.

Activity Scheduling

On some spacecraft, we have found a susceptibility to particular failures if certain events are performed during elevated levels of solar activity. In these cases, we check the solar forecast prior to scheduling the events in order to determine the likeliness of being able to execute them. We also check the space weather again just prior to execution of these events before proceeding in order to avoid problems.

An example of this is a spacecraft that has a change of state in the solar array drive electronics every time we perform a maneuver with elevated solar activity. As the problem involves an illegal state within the control electronics, we have been warned by the manufacturer to limit the number of times that this phenomenon occurs. The worry is that if we let it fail too often, we will weaken the path such that we will not be able to return the state back to normal. Without access to solar weather data, we would not be able to control this.

Another example of this also involves maneuver execution. Prior to performing a maneuver, Loral uses the SEC site to determine whether there is an expected proton event pending. As these types of storms tend to cause problems for the Earth sensing equipment, it is important to keep the spacecraft's attitude quiet during one of these events. If a maneuver were performed during one of these events multiple problems could be encountered. These problems include difficulty in calibrating the attitude fine control sensors, excessive attitude control firings or even potential attitude safety system trips.

Real-Time

In some instances, SEC data is used in real-time to determine the cause of issues. Examples of these are multiple earth sensor glitches or small attitude hold off. All of these have some affect on the pointing of the spacecraft. When these issues occur, the personnel in the SCC check the real-time data on the SEC site to see if there is a link. If the problems are a result of increased solar activity the information is escalated. We create an internal advisement and distribute them. If the activity is of sufficient level escalation will continue to our external customers.

Using the SEC data the SCC is able to determine if a reconfiguration of the spacecraft is warranted, or if the storm is small enough that we can maintain the current configurations. Examples of this reconfiguration are:

If a proton event of sufficient strength is on-going, and expected to continue for sometime, we would disable automatic on-board momentum unloads. As the wheels respond to the increased earth sensor noise, the spacecraft control algorithms mistake this for a buildup of momentum. The spacecraft will then fire thrusters to take care of this momentum. This firing of thrusters should not be occurring as them is no real build up of momentum.

During a magnetic storm, it is very useful to know the expected strength and length of time. This is due to our choices for control methods. For a weaker storm, we could increase the on-board magnetic current to try to compensate. For stronger storms, the increase in on-board magnetic current would not be enough to overcome

the weakness in the Earth's magnetic field. In these cases, we need to go to a thruster control mode. These methods will allow for the continued control of roll. As both methods will cause problems with yaw control, it is important to know how long the storm will continue in order to correct the yaw error.

Post Processing

As part of the due diligence that is performed after every spacecraft anomaly, the SEC data is also analyzed. This is done to see if there is a link between the Solar environment and the anomalous condition. On every fish bone analysis Loral has been a part of, the solar environment plays an important part. Often this information has been critical in identifying the space environment as being the cause. This has led to modification of the spacecraft design to improve its immunity to the spade environment and to eliminate the particular failure mode.

Loral also uses the archive data from the SEC during the spacecraft deign and analysis activities.

Question 3

How would you compare our knowledge today of the impacts of space weather on satellite operations to what we knew five years ago, and to what we expect to know five years from now?

Last five years

During the last five years, we have expanded our understanding of the solar environment greatly. However, the biggest change in the last five years goes beyond what we have learned. The biggest change is in how we utilize it. Five years ago there was less information available (as far as what is being monitored), and it was difficult to work with (fax, paper copies, etc.). This has improved over the last five years to allow better access to the information. Data is now available online and viewable at an individual engineers terminal.

Having this data available has allowed a larger team across the industry to analyze the information to show relations to other events. One example is on one of our spacecraft. If we get a solar storm of sufficient magnitude late in an eclipse season, we often also get a transponder shut off coincident with it.

Having the Solar Environment data available allows us to better understand patterns that might otherwise never be understood.

Next five years

I think the industry push at this point is on two fronts:

1) The need for a more reliable early warning system. There has been much individual work on this from many sources. Though the obstacles to overcome are daunting, this would be the single biggest improvement for the next five years.
2) The improvement in the knowledge of the space environment. Although we have made great strides in understanding of the space environment, there are still several holes in on knowledge. Improved detectors and analysis tools are needed to provide for better spacecraft designs. Another area of improvement is modeling for specific orbit location. This is a 4D (3 axis with time) modeling to view how the local orbit environment changes with time.

Question 4

What would be the impact to your organization if SEC were no longer able to provide its space weather forecasts? Please provide specific examples when possible.

Impact

The impacts to Loral of not being able to access the SEC would be severe. Many of these have been mentioned in the answers to the previous questions.

One spacecraft whose health would be most adversely affected would be the spacecraft that exhibits an anomaly with its solar array drive electronics. On this spacecraft, when a maneuver is performed during elevated solar activity, the solar array drive electronics switches into an illegal state (stopping the solar array). Each time this has happened, the solar array drive electronics have been commanded back into a normal state successfully. There is a concern that if this phenomenon were allowed to occur too often, we would be unable to command the solar array drive electronics back into a normal state. Without the SEC information, Loral would not be able to cancel maneuvers based on solar environment levels and consequently we would not be able to avoid this circumstance.

Service outages would also be more often and longer in duration. By having space weather forecast available, Loral is able to prepare in advance for potential situations. For example if a major proton event is expected (or occurring), the spacecraft can be configured to better ignore earth sensor glitches. In addition, the Satellite Control Center (SCC) can be prepared for potential anomalous events associated with the storm. In the case of an earth sensor glitching problem growing to a more serious problem on the spacecraft, the SCC can often reconfigure before any problems affects service. In the case of a magnetics loss of control, the sooner the SCC configures the spacecraft for the solar storm, the lower the attitude error will be.

Another way in which Loral would be affected is the overall spacecraft design quality. Spacecraft Manufacturers use information learned in anomaly investigations to improve their future designs. The better they are able to determine root causes to problems, the better they will be able to improve their designs. The best way to ensure the highest quality root cause analysis is to ensure access to the best data. This includes in-orbit telemetry data, design documents and space weather data. If information on the space environment were not available the spacecraft manufacturer would note able to consider this in the design and testing of his spacecraft or correlate design improvements on orbit.

APPENDIX C

Real Time Example Of Space Weather Alert

-----Original Message-----
From: Speckhardt, Martin P.
Sent: Friday, October 24, 2003 11:17 AM
To: Grp: MLT; Grp: Marty Speckhardt; Grp: M. Morgan; Grp: Rick Mortellaro; Grp: P. Attner; Grp: Sun Managers; Moorthy, Sundaram; Tarpley, C. Scott; Skimmons, Brian; Trowbridge, Amy; Hill, Roger; Dannwolf, Jurgen W.; Thompson, William G.; Acocella, Michael D.
Subject: Code Orange Declared for the Fleet

**********Code Orange Emergency Notification**********

Operations has declared a code orange due to pending elevated solar weather. The code orange will be in affect through the weekend, and revisited on Monday. This is due to the cause of the solar weather. As can be seen in the attached picture, there is one large sunspot facing earth. This sunspot has emitted multiple flares. Elevated weather is expected for the next two days. Any additional flares may extend the duration of elevated weather.

All maneuvers and other operations that can be delayed will be delayed until the end of the storm. Operations will continue to track the storm and be prepared to react in the event of any problems.

Progress of the storm can be followed by using the following link available http://www.n3kl.org/sun/noaa.html.

This Code Orange will be rescinded at the end of the storm.

DISCUSSION

Chairman EHLERS. And thank you. And thank you to all of the witnesses. Very good testimony.

We will now proceed with questions. And the Chair will ask the first questions. We each have five minutes, and we will—and that includes both the question and your answer, but we won't cut your answer off in mid-sentence, so don't worry about that.

SPACE ENVIRONMENT CENTER (SEC) FUNDING

First, I have a question. I hate to ask yes or no questions, but this is a simple one, and I would like to ask each of you to respond with a yes or no answer. In your opinion, should the Federal Government reduce or eliminate funding for NOAA's Space Environment Center? Dr. Hildner.

Dr. HILDNER. My answer is that the funding should not be reduced or eliminated.

Chairman EHLERS. Colonel Benson.

Colonel BENSON. No.

Chairman EHLERS. Dr. Grunsfeld.

Dr. GRUNSFELD. No.

Chairman EHLERS. Kappenman.

Mr. KAPPENMAN. No.

Chairman EHLERS. Krakowski.

Captain KRAKOWSKI. No, sir.

Chairman EHLERS. Hedinger.

Dr. HEDINGER. No, sir.

Chairman EHLERS. Thank you.

THE APPROPRIATE ORGANIZATION FOR FORECASTING SPACE WEATHER

Second is—I would like to ask another question. Is there a compelling reason why the functions of the SEC should be moved to another agency, without specifying the agency? For example, is NOAA not providing services to you at the expected level or in the useful manner, or do you think some other branch of government would be more effective? Again, we will go reverse this time. Dr. Hedinger.

Dr. HEDINGER. I believe the NOAA SEC is the most appropriate place to have this fall.

Chairman EHLERS. Okay. Captain Krakowski.

Captain KRAKOWSKI. Mr. Chairman, we believe that this is one of the finest examples of a well-running effort, and we don't see any reason at all to make a change.

Chairman EHLERS. Mr. Kappenman.

Mr. KAPPENMAN. Since I wear both the power industry hat as well as a commercial provider that essentially competes with SEC in some aspects, I would like to answer that we think SEC is the most appropriate agency from both perspectives.

Chairman EHLERS. That reminds me, incidentally, of someone I knew who once questioned the need for NOAA and the National Weather Service said, "I get all of the weather I need from the TV programs." Since you—unfortunately, it was a Congressman, but

he lost his next election. But at—from your position as both a user and competitor, that is a very meaningful answer.

Dr. Grunsfeld.

Dr. GRUNSFELD. I think that the Space Environment Center and its relationship with NASA and I know for the United States Air Force and NOAA that this is a good example of how government agencies work well together, so I see no compelling reason why we would want to move it.

Chairman EHLERS. Colonel Benson.

Colonel BENSON. I—sir, I would see no compelling reason to move the functions.

Chairman EHLERS. And Dr. Hildner, I assume I know your answer, but go ahead.

Dr. HILDNER. I think you know NOAA's answer, but let me comment that our partnerships with the other agencies are already so good that I see no compelling reason to move space weather services out of NOAA.

Chairman EHLERS. I—let me just add that—I believe it was Captain Krakowski mentioned another point and that is, although I am sure that one of the military arms of the government could easily do this, there is also the possibility of filtering during a time of national emergency that simply the information would not flow freely. And I think we want to avoid that as well, in spite of their ability to do this.

Another follow-up question on that, and that is, would it make any sense for a non-governmental agency to do this either on a fee-for-service basis, excuse me, or under government contract? And we will go this way again. Dr. Hildner.

Dr. HILDNER. Thank you.

We regard space weather as extremely analogous to the meteorological weather service. And so many of the arguments that we apply to the meteorological services and why those should be free to all users I believe apply equally to the space weather service. Let me comment with Mr. Kappenman sitting here that NOAA tends to predict and synthesize the space weather environment, and we leave it to commercial folks, for a fee, to tailor those products to specific systems that are affected by space weather events.

Chairman EHLERS. Colonel Benson.

Colonel BENSON. No, sir, I wouldn't be in favor of changing who provides the data and how it is being procured.

Chairman EHLERS. Dr. Grunsfeld.

Dr. GRUNSFELD. Well, at NASA, we are very protective of our national assets in space, as I am sure the Air Force is, as well. And we have a very good relationship with the SEC in meeting our needs, and I think we see no reason why we would want to change that.

Chairman EHLERS. Mr. Kappenman.

Mr. KAPPENMAN. I also don't believe that it would be very practical or efficient to transfer this sort of function wholly to a commercial provider.

And if I could just speak a few seconds on the nature of the partnerships that we see developing in the commercial providers of space weather forecasts versus what NOAA does. If we look at NOAA's mission, they are to provide public information. And we ac-

tually see the medical industry as being how we are aligning ourselves and forming ourselves. Where NOAA is the general practitioner, handles most of the medical situations, but where you have a very serious space weather health problem from an infrastructure operator standpoint, you should be working with a specialist who can take that NOAA information and also knows how your infrastructure is impacted and work with you very closely on those very serious problems.

Chairman EHLERS. Are you going to change your name from Applied Power to Applied Clinic?

Captain Krakowski.

Captain KRAKOWSKI. When I consider the evolution of our navigation systems to become more dependent on satellites, and the FAA is another government agency that we have to work with in our navigation and communication issues, it seems like keeping it within a federal functionality seems right to us.

Chairman EHLERS. Okay. Dr. Hedinger.

Dr. HEDINGER. Thank you.

Yes, at this point in time, I think that the services that are provided by NOAA SEC are generally applicable across a very broad environment, which is the right place to have a government service provide it. It spans the commercial industry, the government industry, and very many other types of functions. Clearly, there are opportunities for some secondary applications that would be in the area of this—that we have just described here. But the functions that NOAA SEC perform would definitely be——

Chairman EHLERS. Thank you for your comments. My time is expired, but I hope you will also, as individuals, express those opinions outside this room with the other Members of Congress who are involved in this situation.

My time is expired. I am pleased to recognize the Ranking Member, Mr. Udall.

SEC BUDGET COMPARED TO OTHER FEDERALLY FUNDED PROGRAMS

Mr. UDALL. Thank you, Mr. Chairman. If I might, I would like to build on your line of questioning and start with the three witnesses who serve in the public sector.

And if I could, I would like to put the SEC's $8 million budget into context. As I see it, the—that budget is a very small part of the total federal budget for space weather. And Dr. Hildner, if I could start with you and move across, how does the SEC's budget compare with federal funding for the design, development, acquisition, and operation of space and ground-based sensors and for the research that has made space weather possible?

Dr. HILDNER. I am reluctant to answer about the details of the expenditures in other agencies, but I believe that it is in the billions—or a billion dollars or so of research and sensor development for—that is applicable to space weather.

Mr. UDALL. Colonel Benson.

Colonel BENSON. Could you repeat your question, sir?

Mr. UDALL. What I was trying to get at is we spend $8 million for the SEC function, but I wanted to put that in the context of all

of the assets that we deploy as well as the research and development that we do in other federal arms.

Colonel BENSON. I can't speak for the total amount in the rest of the federal arms, but it is a minute fraction compared to the value of the assets that we have on orbit and that we spend for R&D.

Mr. UDALL. Dr. Grunsfeld, before you reply, I just want to welcome you. It is nice to see you again. Dr. Grunsfeld visited Boulder and the Ball Aerospace Company and has done some great work in repairing the Hubble Telescope as a space walker. And he is also a climber, and he fit in that comment about the—that small subset of interested people who ascend high mountains above 8,000 meters who would be subject to space weather events. And we want to take care of those people as well. So welcome, and great to see you here.

Dr. GRUNSFELD. Thank you very much. Thank you for that recognition.

The—NASA has, you know, quite a few number of assets. Just in space science alone, I think we have about 30 satellites that are operational right now, including the Hubble Space Telescope, which, I think, was about $1.6 billion. And so if you look at the $8 million as a kind of insurance policy, you know, it would be an usually small percentage compared to any other insurance that anybody would consider. It is, you know, certainly less than a percent.

Mr. UDALL. Thank you. And yes, it is great to see you here, and thanks for all that you do.

PRIVATE SECTOR INTERACTION WITH THE SEC

If I could extend now a set of questions to those of you from the private sector, and your testimony, I think, was very compelling. And I think you have answered this in part, but I want to give you another chance to amplify on your comments. Is your interaction with the SEC a one-way interaction? In other words, do you receive these forecasts or do you—are you also in a position where you are solicited for advice and input from the SEC?

Mr. KAPPENMAN. Clearly, it is a two-way relationship. We depend, of course, very heavily upon the SEC to gather and disseminate data at high quality, high cadence that is needed for these environments. We do have a very successful and healthy interaction on what the important features of the environment are, where we can both serve the Nation and the important infrastructures better through things that we can do better in the space environment fields.

Captain KRAKOWSKI. While we use their products on a daily basis, the products themselves are not very useful unless we understand how to use them. And I think one of the greatest interactions of SEC was them opening their doors to us and their arms to have us come out to Boulder and learn all about this phenomena before we started to do this kind of flying. So it is very interactive and we do appreciate their warmth and their ability and willingness to help educate companies like ours on these sorts of issues.

Mr. UDALL. Dr. Hedinger.

Dr. HEDINGER. Thank you.

Yes. I would like to reiterate that this is a very interactive relationship and a very customer-friendly relationship. The progress that has been made here in the last five years of getting real-time online access to data that we use on a day-to-day basis. In fact, our satellite control center right now is determining how to reconfigure satellites to minimize impacts.

Mr. UDALL. Thank you.

SEC IMPROVEMENTS WITHIN THE CURRENT BUDGET

If I could turn back to Dr. Hildner. Dr. Hedinger testified that Loral Skynet expects to see a series of things over the next five years: a more reliable warning system, improvements in knowledge of the space environment, improvements in dynamic modeling for specific orbit locations, and other changes and added products. Do you think NOAA or other partner agencies could supply these improvements if the funding level would remain at the $5 million proposed point at this time?

Dr. HILDNER. No. I could amplify that answer, if you would like.

Mr. UDALL. I—no, I think that is perfect.

If I might just get one last question in and to Dr. Hildner once again. The testimony here, I think, suggests that we ought to be investing more in space weather. I am assuming that the budget, the Administration's budget of $8 million would maintain current capabilities and provide some funding for improvements. What opportunities would we be missing if we don't invest in additional efforts when it comes to space weather forecasting?

Dr. HILDNER. You are absolutely correct that at the President's requested level we would be able to maintain our operations and make modest improvements. But we stand at a confluence of increasing demands, and some of which you have heard about today, and expectations from our customers, and at the same time, a great increase in opportunity. The DOD, NSF, and NASA are spending a great deal of money for research, new sensors, and so forth, which SEC, even at the President's requested budget, will not be able to incorporate into operations. In other words, the Nation's investment in space weather services improvements will not be garnered if SEC continues on at its current level of effort.

Mr. UDALL. I thank the panel and the Chairman for his forbearance in extending a little more time to me. This is a very important topic. Thank you again.

Chairman EHLERS. Thank you.

We have a few more questions, and so we will start a second round. I understand Mr. Gutknecht does not—so I will begin with the second round. And I would point out, incidentally, before I do that, that again, I did a quick mental calculation. If you should receive the President's request, which is $8 million, that comes to just a bit more than three cents per capita in the United States. When you consider that if a commercial satellite went out that was carrying a television program, everyone would spend eight cents to call their TV—cable provider to complain, they would spend more than twice as much as they are spending to maintain the warning system.

SENSORS ABOARD THE AGING ADVANCED COMPOSITION EXPLORER (ACE) SPACECRAFT

My next question is for Dr. Hildner, Grunsfeld, and Colonel Benson. One of the most vital sensors for providing advanced warning in radiation and magnetic storms is located on, pardon me, NASA's Advanced Composition Explorer, sometimes called the ACE spacecraft. Yet this spacecraft is currently operating beyond its design life and there are no plans to continue collecting this type of solar wind data once ACE ceases to operate. Are NOAA, NASA, and the Air Force planning for a way to continue obtaining this vital data? And we will start with NOAA on this one. Dr. Hildner.

Dr. HILDNER. The difficulty with the ACE spacecraft approaching its end of life and the possibility of not getting those enormously important data has been recognized in NOAA. And we are considering requesting the Congress for additional funds to obtain those data.

Chairman EHLERS. Let me just ask, the NPOESS satellites will be going up. It is a joint Air Force/NOAA effort. Could a—could one of these sensors be added to that satellite?

Dr. HILDNER. NPOESS will have an improvement in the near-Earth space environment sensors, but because they are in polar orbit near Earth, they do not give us that advanced warning that the ACE satellite does one percent of the way from the Earth toward the sun out in the solar wind.

Chairman EHLERS. One percent, you said, of the distance?

Dr. HILDNER. The ACE is stationed at——

Chairman EHLERS. It is about nine million miles?

Dr. HILDNER. It is about——

Chairman EHLERS. Fifteen kilometers——

Dr. HILDNER. About one million miles. It is 93 million miles to the sun, so one percent——

Chairman EHLERS. Right.

Dr. HILDNER [continuing]. Is about one million miles——

Chairman EHLERS. Yeah. Right.

Dr. HILDNER [continuing]. Toward the sun from Earth, and that is the place where the Earthward forces and the sunward forces balance and the spacecraft will sit there.

Chairman EHLERS. Yeah.

Colonel Benson.

Colonel BENSON. Sir, we rely on the ACE data for the solar wind estimation. The Air Force has just launched, as of two weeks ago, a new block of DMSP satellites, Defense Meteorological Satellite Program. And in this new block of satellites, we have a series of space weather sensors on there. But they are in the low-Earth orbit, and they don't have a package specifically designed to do what the ACE program does.

Chairman EHLERS. Dr. Grunsfeld.

Dr. GRUNSFELD. Hopefully the ACE spacecraft will keep operating beyond its nominal lifetime margin for a good, healthy long time. And the National Academy, in its NRC report, did identify the source of these types of data as being critically important. And so that is something that the Office of Space Science, you know, has in its strategic planning. But as yet, I am not specifically

aware, for our research activities, of any plans to replace that capability.

Chairman EHLERS. Is this an expensive satellite?

Dr. GRUNSFELD. It is one of our explorer class satellites, and, you know, I am not sure what, in this context, "expensive" is. It is not—you know, it is not in the, you know, great observatory class. It is one of the smaller satellites.

Chairman EHLERS. Yeah. Okay. I—we will have to pursue that in the Committee, and—because I think that is a self-evident thing to do.

Dr. GRUNSFELD. And we can provide you with more information about some of the experiments in the pipeline and how they might relate to this.

Chairman EHLERS. All right. I would appreciate that, because it shouldn't be that expensive if it is a single-purpose satellite. It takes—of course, it takes a fair amount of horsepower to get it up that far, but that is something we will pursue.

I have no other questions at the moment. Mr. Udall, do you have——

VULNERABILITY TO INDUSTRY FROM SPACE WEATHER EVENTS

Mr. UDALL. Thank you, Mr. Chairman. I would like to take this opportunity to direct a couple of questions at the witnesses from the private sector.

Would you say that your organizations operations have become more vulnerable to space weather events over time or is it solely a matter of having gained a better understanding of the link between space weather events and specific problems you encounter during operations? Again, we can start with Mr. Kappenman and move across.

Mr. KAPPENMAN. Yeah. In the prepared testimony, I do cite quite a bit of evidence that the power industry has learned that indicates that we are, because of various design changes, growth of the power grid and so forth, we are unequivocally growing more and more vulnerable to space weather. That being said, we are also learning much about space weather impacts. And we may not know exactly how vulnerable we really are. We know right now we are extremely vulnerable.

Mr. UDALL. Um-hum.

Mr. KAPPENMAN. And we also know that it is not going to be easy to become unvulnerable or invulnerable and undo what has essentially transpired through billions of dollars of investment in infrastructure, 50 years or more of development of that infrastructure.

Mr. UDALL. Captain Krakowski.

Captain KRAKOWSKI. Thank you, sir.

Yeah, we are—five years ago, were it not for the ability to have airplanes fly over 16 hours, we really could not even entertain dealing with such a risk. But now with the commercial opportunities opening up wider between Asia and the United States and the ability to fly longer range flights with the new technology airplanes coming up, this is somewhat new to us——

Mr. UDALL. Um-hum.

Captain KRAKOWSKI [continuing]. Which is why we are so interested in it.

The other aspect of it is, well, as we contemplate moving more toward GPS-type navigation systems and away from land-based systems, there is an additional concern of what this kind of weather—solar weather impact would mean to that very critical infrastructure. And I think we are still in the learning mode with some of that.

Mr. UDALL. Dr. Hedinger.

Dr. HEDINGER. Thank you, Congressman Udall.

I think there are really two areas here. One is just the volume of services that have grown over the last several years. An example is the direct to home market. Now we have approximately 20 million households erect a home receiver. Five years ago, how many was that? But it has changed dramatically, and that continues to grow. But it is just the amount of business that is in space, the amount of business that depends on space for its revenue, so that is becoming more critical.

The other thing is the new technologies that are being developed. With the—there is a move toward on-board processing to be able to provide more efficient communications and more economical access services. An example is the new KA band on-board processing satellites. These are likely to be more sensitive to space weather since there are computer chips, et cetera, on board the spacecraft.

Thank you.

VULNERABILITY TO FEDERAL AGENCIES FROM SPACE WEATHER EVENTS

Mr. UDALL. Perhaps I could ask the government witnesses to comment on this as well, if you would, and again, Dr. Hildner—and I—if I restate the question. Would you say that organizations in the government operations have become more vulnerable to space weather events over time or is it solely a matter of having gained a better understanding of the link between solar weather events and specific problems that we encounter during operations?

Dr. HILDNER. I would say it is the former. We have become more vulnerable, and partly because we have become more technological and those technological systems, as we become more dependent upon them, they, in fact, are becoming more vulnerable. And so we are becoming more vulnerable.

Mr. UDALL. Colonel Benson.

Colonel BENSON. Sir, I would agree with Dr. Hildner. I think we are more vulnerable as we require—rely more and more on space-based assets. Those vulnerabilities are there for the assets that we have on orbit. Even our Global Positioning System has effects from space weather as far as the errors that are driven by space weather events. So our dependency on GPS has also magnified the impacts of a space weather event on navigation systems.

Mr. UDALL. And I—space command based in Colorado, and I was sure that General Lord and others would underline what you had to say about the effects on our space command.

Dr. Grunsfeld.

Dr. GRUNSFELD. Well, I think first and foremost, we are interested in the safety of our crew. And I am very proud to say that,

you know, we are coming up on having three years of human international crews living in space all of the time, 365/24/7. And so in that respect, we certainly are more vulnerable. In addition, we are kind of a victim of our own success in technology in that the capability of the microchips and the technology that goes into constructing all of the space assets that we have talked about have gotten a lot smaller and more compact and using technology that, in a sense, is more vulnerable to space radiation.

RELATIONSHIP WITH THE INTERNATIONAL COMMUNITY

Mr. UDALL. I thank the panel, and I might extend a request to the Chairman, I—we—one area we didn't cover was the relationship we have with the international community and their space weather forecasting capabilities and how we coordinate and whether there would be an effective—if the SEC was to be put out of business or the funding—the necessary funding wasn't in place, but——

Chairman EHLERS. Dr. Hildner, if you would just like to just answer that, comment on that.

Dr. HILDNER. I would be happy to. In the interest of time, we had not mentioned our international partnership. There is an outfit called the International Space Environment Service. It has 12 regional warning centers around the world. NOAA's center in Boulder is one of those regional-warning centers. All of those centers exchange data actually through Boulder every day. And then Boulder synthesizes all of that information and puts out the global forecast as the world-warning agency of the International Space Environment Service. Of course, that would all go away if we were eliminated.

THE VITAL ROLE AND RESPONSIBILITIES OF THE SEC

Chairman EHLERS. The gentleman's time is expired. I would just like to conclude this hearing by several comments. First of all, it is obvious to me from your comments, Mr. Udall, that far too much government money is going to Colorado. And probably the SEC should move to Michigan where it would be closer to the *Aurora Borealis.* You could at least have the pleasure of observing that. More importantly, it is clear from today's hearing that the services that NOAA's SEC provides are unique and vital to our nation and its citizens every day, much more so than people realize, and as we just heard, also important to those of other countries.

Secondly, it is neither within the mandate nor the mission of the Air Force or NASA to take on these crucial responsibilities. And it is my opinion that a transfer of this sort, at this time, would require significant expenditures on the part of the Federal Government and certainly above the $8 million sought by the Administration for the SEC. It would also be very disruptive to the entire program.

So I believe that it is certainly advisable that this committee go on record as preserving the SEC precisely where it is. There is no reason to change it. "If it ain't broke, don't fix it," as the old saying goes, and so let us keep it going. And I hope—we will certainly pass this information on to the appropriators in the House and

Senate. And I hope that all other interested parties would express that as well.

The fact that we are discussing this precisely as a space storm is occurring, and I understand that Japan has lost—temporarily lost one satellite and is about to lose another, indicates the importance of the work that is being done here.

Before I close, I just simply have a little housekeeping. I, first of all, want to thank you very, very much for your participation. We couldn't have had a better panel, broadly representative of the issue in both the governmental sector and the industry, and I appreciate your time. And above all, I appreciate your wisdom. So thank you for taking the time to be here.

If there is no objection, the record will remain open for additional statements from the Members and the answers to any follow-up questions the Subcommittee may ask of the panelists. And without objection, so ordered. And I would assume you would be willing to respond to questions in writing, should they come up.

Thank you again for your service, and it is my pleasure to declare the hearing adjourned just in time for another vote. The hearing is adjourned.

[Whereupon, at 12:03 p.m., the Subcommittee was adjourned.]

Appendix 1:

Biographies, Financial Disclosures, and Answers to Post-Hearing Questions

BIOGRAPHY FOR ERNEST HILDNER

Dr. Hildner is the Director of NOAA's Space Environment Center. The Center is the Nation's 24-hour-a-day center for alerts, warnings and watches related to space weather. Under his direction, SEC also conducts research and consults on space weather instrument development for NOAA, NASA, and the Aid Force.

Dr. Hildner is a solar physicist who has worked for the High Altitude Observatory, NCAR, and at NASA Marshall Space Flight Center as head of its Solar Physics Branch. He was fortunate to be experiment scientist for Skylab and the Solar Maximum Mission during the 70's. His scientific speciality is coronal and interplanetary physics, in which he has published dozens of papers. He co-holds one patent for a variable-magnification x-ray telescope.

In addition to his administrative responsibilities with NOAA, Dr. Hildner is a Co-chair of the Committee on Space Weather for the National Space Weather Program, is a member of the advisory committees for the NOAO National Solar Observatory and NCAR High Altitude Observatory, and serves on review panels for NASA and DOD projects.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ernest Hildner, Director, Space Environment Center, National Oceanic and Atmospheric Administration

Space Environment Center

Q1. In Col. Benson's written testimony it is mentioned twice that the complementary nature of the Air Force Space Weather Operations Center and the SEC allows each agency to realize significant cost savings. What is the dollar amount saved as a result of the Air Force and NOAA collaboration on space weather?

A1. The National space weather enterprise, with complementary service centers in NOAA and U.S. Air Force Weather, depends on a critical shared database with contributions from NOAA and the USAF complementing each other. However, the savings to the Nation go far beyond the collaborating service centers. NOAH would have to replace and pay for a large fraction of the USAF-provided data if USAF no longer provided it. Conversely, USAF would have to pay tens of millions of dollars per year for the sensors and their data now provided by NOAA, should NOAA no longer provide them.

USAF operates the ground-based Solar Environmental Observing Network of observatories around the world. NOAA has no equivalent data in the near-term for the data provided by this ~$20M per year network. Additionally, USAF pays the U.S. Geological Survey $150k per year to help it operate a ground-based magnetometer network so the data can be provided in near real-time to both USAF and NOAA. NOAA's Space Environment Center distributes to the public some products created at U.S. Air Force Weather Agency's center in Omaha; one of these is the immediate, three-hourly estimate of the value of the index characterizing global geomagnetic activity. This index is of great interest to civilian users; NOAA would have to create the product if USAF did not, at an estimated expense of $2M to port the software. Finally, USAF Space Command flies sensors on the Defense Meteorological Space Program (DMSP) series of spacecraft. The data are archived at NOAA's National Geophysical Data Center and used by Space Environment Center. The model NOAA plans to use to characterize and predict the ionosphere is being developed with USAF funding of about $10M and will be driven by data from DMSP. NOAA will save the $10M up-front cost of the model and the annual cost of fabricating and flying the instruments and getting the data because of USAF investments.

In all, we estimate that NOAA would have to spend several tens of millions of dollars per year to sustain the same level of services if USAF dropped from the national collaboration in space weather.

Q2. One of the most vital sensors for providing advanced warning of radiation and magnetic storms is located on NASA's Advanced Composition Explorer spacecraft. Yet, this spacecraft is currently operating beyond its design life and there are no plans to continue collecting this type of solar wind data once ACE ceases to operate. Are NOAA, NASA and/or the Air Force planning for a way to continue obtaining this vital data? If so, please explain the strategy.

A2. Real-time solar wind measurements from upstream of Earth, now obtained from NASA's ACE research spacecraft, are among the most vital data for providing space weather services. The ability to warn of geomagnetic storms approximately an hour in advance is due solely to these data. Delayed solar wind measurements, available from other NASA spacecraft operating in a "store and dump" mode, are of no operational benefit, though they have research value. ACE has already completed its prime research mission, but has been selected by NASA for extended operations, because of new, high-priority scientific goals that can be addressed with this valuable national asset. The spacecraft has enough propellant on board to maintain its new, looser, non-optimal for space weather purposes, orbit around Lagrange Point 1 (L1) until late into the next decade.

ACE has been a unique resource in that it continuously transmits, all day—every day, in near real-time, solar wind and energetic particle data that can be acquired by relatively small ground-based antennas. No other spacecraft can do that; unless the ACE capability for space weather is replaced, when ACE dies NOAA, its partners, industrial space weather service companies, and end users will all lose valuable products and services. Geomagnetic storms are especially important to electric power grid operators and radio communicators (including airlines).

NOAA, NASA and the USAF, will continue to consider options for providing ACE-like data.

BIOGRAPHY FOR CHARLES L. BENSON, JR.

Colonel Charles L. Benson, Jr., is commander of the Air Force Weather Agency. He leads over 900 agency members at 20 locations around the world providing centralized weather products and services, including climatological and space weather support, to USAF, U.S. Army, special operations national intelligence community and other DOD activities. He executes a worldwide weather support mission, that provides decision assistance to combat, reconnaissance, command and control, presidential support, treaty verification and airlift missions directed by the Joint Chiefs of Staff, theater commanders, and major command commanders.

Colonel Benson has served as a wing weather officer in Korea; executive assistant to the Commander, Air Weather Service, Scott AFB, IL; and Chief of the Advanced Systems Management Section, Offutt AFB, NE. He has commanded a weather detachment in Kansas and served as a program element monitor in Headquarters USAF's Directorate of Weather. Colonel Benson was assigned to Headquarters USAF's Directorate of Operational Requirements as Chief of Force Enhancement Requirements. He has served as Director of Weather for Headquarters Air Mobility Command's Tanker Airlift Control Center; Chief of Protocol for the Commander in Chief, United States Transportation Command; and Deputy Commander, 60th Support Group, Travis AFB, California.

Prior to his arrival at Offutt AFB, Colonel Benson commanded the United States Air Force Academy's 34th Support Group.

EDUCATION

1977 Bachelor of Science degree in Meteorology, Texas A&M University
1978 Officer Training School, Maxwell Air Force Base, Ala.
1985 Master's degree in Meteorology, St. Louis University
1986 Air Command and Staff College (Correspondence)
1990 Distinguished Graduate, Naval War College's Naval Command & Staff, Naval War College, Newport, R.I.
1991 Master's degree in National Security & Strategic Studies, Naval War College, Newport, R.I.
1995 Air War College, Maxwell Air Force Base, Ala.

ASSIGNMENTS AND DATES

1. September 1978–April 1981, wing weather officer, 463rd Tactical Airlift Wing, Dyess AFB, Texas
2. April 1981–June 1982, wing weather officer, 8th Tactical Fighter Wing, Kunsan Air Base, Korea
3. June 1982–January 1984, executive assistant to the commander, Air Weather Service, Scott Air Force Base, Illinois
4. January 1984–June 1985, student, St. Louis University, St. Louis, Missouri
5. June 1985–October 1987, chief, Advanced Systems Management Section, Air Force Global Weather Central, Offutt Air Force Base, Nebraska
6. October 1987–August 1990, commander, Detachment 23, 9th Weather Squadron, McConnell Air Force Base, Kansas
7. August 1990–December 1991, student, Naval War College, Newport, R.I.
8. December 1991–November 1992, program element monitor, Deputy Chief of Staff for Air and Space Operations, Headquarters U.S. Air Force, Washington, D.C.
9. November 1992–August 1994, chief, Force Enhancement Requirements, Directorate of Operational Requirements, Deputy Chief of Staff for Air and Space Operations, Headquarters U.S. Air Force, Washington, D.C.
10. August 1994–June 1995, student, Air War College, Maxwell Air Force Base, Alabama
11. June 1995–September 1997, director of weather, Tanker Airlift Control Center, Headquarters Air Mobility Command, Scott Air Force Base, Illinois
12. September 1997–August 1998, chief of protocol, U.S. Transportation Command, Scott Air Force Base, Illinois
13. August 1998–April 1999, deputy commander, 60th Support Group, Travis Air Force Base, California
14. April 1999–May 2001, commander, 34th Support Group, U.S. Air Force Academy, Colorado Springs, Colorado
15. May 2001–August 2002, vice commander, Air Force Weather Agency, Offutt Air Force Base, Nebraska
16. August 2002 to Present, commander, Air Force Weather Agency, Offutt AFB, Nebraska

AWARDS AND DECORATIONS

Legion of Merit
Meritorious Service Medal with five oak leaf clusters
Air Force Commendation Medal with one oak leaf cluster
Air Force Achievement Medal

EFFECTIVE DATES OF PROMOTION

Second Lieutenant August 15, 1978
First Lieutenant August 15, 1980
Captain August 15, 1982
Major June 1, 1989
Lieutenant Colonel June 1, 1993
Colonel April 1, 1999

ANSWERS TO POST-HEARING QUESTIONS

Responses by Colonel Charles L. Benson, Jr., Commander, Air Force Weather Agency

Questions submitted by Chairman Vernon J. Ehlers

Vital Sensors

Q1. One of the most vital sensors for providing advanced warning of radiation and magnetic storms is located on NASA's Advance Composition Explorer (ACE) spacecraft. Yet, this spacecraft is currently operating beyond its design life and there are no plans to continue collecting this type of solar wind data once ACE ceases to operate. Are NOAA, NASA and/or the Air Force planning for a way to continue obtaining this vital data? If so, please explain the strategy.

A1. Air, Force Weather (AFW) has a requirement for solar wind data, but does not field space-based systems. AFW has advocated for solar wind data and will continue to do so. We continue to advocate for environmental monitoring capabilities and to leverage existing and proposed Air Force Space Command, NASA, and NOAA satellites and sensors. Once ACE ceases to operate, we will be without the data it provides with no other viable alternative system immediately available.

Dollar Amount Saved

Q2. In your written testimony it is mentioned twice that the complementary nature of the Air Force Space Weather Operations Center and the SEC allows each agency to realize significant cost savings. What is the dollars amount saved as a result of the Air Force and NOAA collaboration on space weather?

A2. The estimated annual space weather operations cost savings for the Air Force Weather Agency (AFWA) is $11.4M. This cost savings is comprised of $6.8M from leveraging the research and technology transition performed by SEC. Additionally, there would be an up-front cost (significantly greater that the annual operation costs of ~$10M) to initially set up all of SEC's operations and research at AWA, if SEC's mission was transferred to the Air Force.

BIOGRAPHY FOR JOHN M. GRUNSFELD

PERSONAL DATA: Born in Chicago, Illinois. Married to the former Carol E. Schiff. They have two children. John enjoys mountaineering, flying, sailing, bicycling, and music. His father, Ernest A. Grunsfeld III, resides in Highland Park, Illinois. Carol's parents, David and Ruth Schiff, reside in Highland Park, Illinois.

EDUCATION: Graduated from Highland Park High School, Highland Park, Illinois, in 1976; received a Bachelor of science degree in physics from the Massachusetts Institute of Technology in 1980; a Master of science degree and a doctor of philosophy degree in physics from the University of Chicago in 1984 and 1988, respectively.

ORGANIZATIONS: American Astronomical Society. American Alpine Club. Experimental Aircraft Association. Aircraft Owners and Pilot Association.

SPECIAL HONORS: W.D. Grainger Fellow in Experimental Physics, 1988–89. NASA Graduate Student Research Fellow, 1985–87. NASA Space Flight Medals (1995, 1997, 1999, 2002). NASA Exceptional Service Medals (1997, 1998, 2000). NASA Distinguished Service Medal (2002). Distinguished Alumni Award, University of Chicago. Alumni Service Award, University of Chicago. Komarov Diploma (1995), Korolov Diploma (1999, 2002).

EXPERIENCE: Dr. Grunsfeld's academic positions include that of Visiting Scientist, University of Tokyo/Institute of Space and Astronautical Science (1980–81); Graduate Research Assistant, University of Chicago (1981–85); NASA Graduate Student Fellow, University of Chicago (1985–87); W.D. Grainger Postdoctoral Fellow in Experimental Physics, University of Chicago (1988–89); and Senior Research Fellow, California Institute of Technology (1989–92). Dr. Grunsfeld's research has covered x-ray and gamma-ray astronomy, high-energy cosmic ray studies, and development of new detectors and instrumentation. Dr. Grunsfeld studies binary pulsars and energetic x-ray and gamma ray sources using the NASA Compton Gamma Ray Observatory, x-ray astronomy satellites, radio telescopes, and optical telescopes including the NASA Hubble Space Telescope.

NASA EXPERIENCE: Dr. Grunsfeld was selected by NASA in March 1992, and reported to the Johnson Space Center in August 1992. He completed one year of training and is qualified for flight selection as a mission specialist. Dr. Grunsfeld was initially detailed to the astronaut Office Mission Development Branch and was assigned as the lead for portable computers for use in space. Following his first flight, he led a team of engineers and computer programmers tasked with defining and producing the crew displays for command and control of the International Space Station (ISS). As part of this activity he directed an effort combining the resources of the Mission Control Center (MCC) Display Team and the Space Station Training Facility. The result was the creation of the Common Display Development Facility (CDDF), responsible for the on-board and MCC displays for the ISS, using object-oriented programming techniques. Following his second flight, he was assigned as Chief of the Computer Support Branch in the Astronaut Office supporting Space Shuttle and International Space Station Programs and advanced technology development. Following STS–103, he served as Chief of the Extra-vehicular Activity Branch in the Astronaut Office. Following STS–109 Grunsfeld served as an instructor in the Extra-vehicular Activity Branch, and worked on the Orbital Space Plane, exploration concepts, and technologies for use beyond low earth orbit in the Advanced Programs Branch. He is currently the NASA Chief Scientist detailed to NASA Headquarters. A veteran, of four space flights, STS–67 (1995), STS–81 (1997), STS–103 (1999) and STS–109 (2002), Dr. Grunsfeld has logged over 45 days in space, including 5 space walks totaling 37 hours and 32 minutes.

SPACE FLIGHT EXPERIENCE: STS–67/Astro-2 *Endeavour* (March 2–18, 1995) was launched from Kennedy Space Center, Florida, and returned to land at Edwards Air Force Base, California. It was the second flight of the Astro observatory, a unique complement of three ultra-violet telescopes. During this record-setting 16-day mission, the crew conducted observations around the clock to study the far ultra-violet spectra of faint astronomical objects and the polarization of ultra-violet light coming from hot stars and distant galaxies. Mission duration was 399 hours and 9 minutes.

STS–81 *Atlantis* (January 12–22, 1997) was a 10-day mission, the 5th to dock with Russia's Space Station *Mir,* and the 2nd to exchange U.S. astronauts. The mission also carried the Spacehab double module providing additional mid-deck locker space for secondary experiments. In five days of docked operations more than three tons of food, water; experiment equipment and samples were moved back and forth

between the two spacecraft. Grunsfeld served as the flight engineer on this flight. Following 160 orbits of the Earth the STS–81 mission concluded with a landing on Kennedy Space Center's Runway 33 ending a 3.9 million mile journey. Mission duration was 244 hours, 56 minutes.

STS–103 *Discovery* (December 19–27, 1999) was an 8-day mission during which the crew successfully installed new gyroscopes and scientific instruments and upgraded systems on the Hubble Space Telescope (HST). Enhancing HST scientific capabilities required three space walks (EVA). Grunsfeld performed two space walks totaling 16 hours and 23 minutes. The STS–103 mission was accomplished in 120 Earth orbits, traveling 3.2 million miles in 191 hours and 11 minutes.

STS–109 *Columbia* (March 1–12, 2002). STS–109 was the fourth Hubble Space Telescope (HST) servicing mission. The crew of STS–109 successfully upgraded the Hubble Space Telescope installing a new digital camera, a cooling system for the infrared camera, new solar arrays and a new power system. HST servicing and upgrades were accomplished by four crew members during a total of 5 EVAs in 5 consecutive days. Grunsfeld served as the Payload Commander on STS–109 in charge of the space walking activities and the Hubble payload. He also performed 3 space walks totaling 21 hours and 9 minutes, including the installation of the new Power Control Unit. STS–109 orbited the Earth 165 times, and covered 3.9 million miles in over 262 hours.

ANSWERS TO POST-HEARING QUESTIONS

Responses by John M. Grunsfeld, Chief Scientist, National Aeronautics and Space Administration

Question submitted by Chairman Vernon J. Ehlers

Q1. One of the most vital sensors for providing advanced warning of radiation and magnetic storms is located on NASA's Advanced Composition Explorer spacecraft. Yet, this spacecraft is currently operating beyond its design life and there are no plans to continue collecting this type of solar wind data once ACE ceases to operate. Are NOAA, NASA and/or the Air Force planning for a way to continue obtaining this vital data? If so, please explain the strategy.

A1. NASA's Advanced Composition Explorer (ACE) was launched in August 1997 from the Kennedy Space Center. It carried six high-resolution sensors and three monitoring instruments to sample low-energy particles of solar origin and high-energy galactic particles with a collecting power 10 to 1,000 times greater than past or planned experiments. In addition, the ACE payload includes a real-time space weather monitoring capability, and NOAA has used this for space weather prediction.

ACE has already completed its prime research mission, and in the 2003 Senior Review process, it was selected for extended operations because of new, high-priority scientific goals that can be addressed with this valuable national asset. The spacecraft has enough propellant on board to maintain an orbit at Lagrange Point 1 (L1) until late into the next decade.

ACE has been somewhat of a unique resource because of the type of solar wind data it collects; therefore, NASA has devised a plan to continue collecting similar solar wind data after ACE ceases to operate. NASA is currently moving the Wind spacecraft into L1 to serve as a "hot" backup to ACE in order to maintain our research capability in the area of solar wind turbulence. The Solar and Heliospheric Observatory (SOHO) will also provide complementary data. NASA believes that these resources will ensure continued research and data collection in this discipline in the event that ACE is no longer able to produce useful scientific research.

Questions submitted by Democratic Members

Q1. Is the ISS currently operating with a waiver due to the lack of functional radiation monitors on board?

A1. No. There are currently several functional radiation monitors on board the International Space Station (ISS), including both Russian and U.S.-provided hardware. There is a waiver in place for the Tissue Equivalent Proportional Counter (TEPC), which is one part of the overall ISS on-orbit radiation monitoring system.

Q1a. Is the fact that the Space Environment Center can provide predictions one of the justifications used to grant the waiver?

A1a. There is no overall waiver granted for radiation monitoring because there is functional equipment currently on orbit. The TEPC waiver was presented and approved at the 10 March 2003 ISS Vehicle Control Board. During the discussions regarding the waiver, continued availability of space weather warnings, alerts, and real-time data on solar proton fluxes from the Space Environment Center (SEC) were mentioned as an additional rationale for why it was acceptable to continue without the TEPC.

Q1b. Is NASA currently depending on the SEC in order to provide direction to the ISS crew about radiation protection actions?

A1b. Yes. Real-time data provided by the SEC are the primary information used in developing recommendations to the flight control team. This team directs the crew to take appropriate actions to minimize their radiation exposure.

Q1c. Did the Space and Life Sciences Directorate highlight the "potential that ground-tracked radiation and forecasting from satellites will be reduced or eliminated in FY 2004 (NOAA)" as a concern in their Stage Ops Readiness Rev. meeting on Sept. 24, 2003, while preparing for the launch of the current ISS crew?

A1c. Yes. The Johnson Space Center (JSC) Space and Life Science Directorate (SLSD) highlighted the potential risk posed by the loss of SEC data in the Sep-

tember 24, 2003 SORR discussions and in the October 2, 2003 Flight Readiness Review (FRR).

Q1d. When does the waiver expire?

A1d. The waiver for the ISS TEPC expired October 31, 2003 and is in the process of being extended to April 2004.

Q2. Is the failure of the TEPC one of the elements that led to the recommendation by two managers responsible for monitoring the ISS environmental systems not to launch the current crew to ISS?

A2. The lack of a functional on-orbit TEPC was one element of the overall degradation of on-orbit real-time environmental monitoring on ISS that raised concerns.

Q2a. Was their ultimate decision to agree to go ahead with the launch based on plans to launch a replacement TEPC aboard Progress Flight 14? When is that launch scheduled to occur?

A2a. Yes. Launching a TEPC on ISS Flight 14P (Progress M–49) was one of the specific items cited in the exception to the ISS Flight 7S (Soyuz TMA–3) CoFR. At the time of the CoFR, 13P was scheduled for launch in November 2003 and 14P was scheduled to launch in January 2004. Since that time, the launch of 13P has moved to no earlier than late January 2004. As a result, NASA has requested that the TEPC be manifested on 13P. The manifest for 13P is still under review.

Q2b. Was the TEPC replacement originally scheduled to fly aboard Progress 12, but removed because it cost too much to certify it to fly on a Russian vehicle?

A2b. The original schedule envisioned launching the TEPC in Nov. 2003 on ISS Flight 13P. However, work on recertifying the TEPC for launch was delayed for several months because of funding issues. Because of this delay, the JSC Engineering Directorate determined that the hardware could not be ready for delivery in time for ISS Flight 13P, so TEPC was moved to ISS Flight 14P. When the 14P Progress missions slipped, NASA requested that the TEPC be manifested on ISS Flight 13P (January 2004). The manifest for ISS Flight 13P is currently under review. This TEPC required additional certification to meet Russian launch requirements (Progress launch vibration test), as well as some additional testing to allow operation in the Russian segment of the ISS (i.e., Russian power qualification).

Q2c. Is it important to have the TEPC installed aboard the ISS no later than January to calibrate it as the Sun approaches the minimum activity levels of its 11-year cycle?

A2c. Ideally, in order to be prepared for the earliest potential maximum crew exposure to solar radiation, the TEPC should be on orbit by April 2004. This date is driven by the following considerations: during the last solar cycle, the time of maximum crew exposure preceded the point of actual solar minimum by nine months; SEC's current projection of future solar activity levels places solar minimum sometime between January 2006 and July 2007. Using January 2006 as the earliest possible date for solar minimum, the point of maximum crew exposure would be nine months earlier—or April 2005. If the TEPC is on orbit by April 2004, NASA will be able to collect data for at least one year prior to the point of maximum crew exposure; this will allow us to develop a baseline of performance for the TEPC on orbit, as well as to track the exposure rise to solar minimum.

BIOGRAPHY FOR JOHN G. KAPPENMAN

Education

Graduated with High Honors from South Dakota State University in 1976 with a Bachelor of Science degree in Electrical Engineering. Member of Eta Kappa Nu, Tau Beta Pl, and Phi Kappa Phi Honor Societies.

Professional Experience

1998–Present Metatech Corp, Joined firm in Senior Management Position as Division Manager of Applied Power Solutions Division. He directs the development of products, services, and consulting that are provided to clientele world-wide and primarily focusing on Geomagnetic Disturbances & Space Weather, Lightning, and substation and power system engineering and related specialty products.

1977–1998 Minnesota Power Held a number of professional positions in the organization, 1978–1980 Special Studies Engineer, 1981–1994 Supervisor of Transmission Planning Department, Responsible for Development and Conceptual Design in excess of $100 million in Transmission Construction Projects. 1994–1998 Manager of Transmission Power Engineering Department. Responsible for Substation and Control Engineering Functions arid associated Technology Transfer.

1995–1998 University Minnesota-Duluth Dept. of Electrical & Computer Engineering—Instructor for Senior Technical Elective Courses in Power Systems and Senior Seminar.

Other Professional Activities; Faculty Member of the Electromagnetic Transients Program extension courses held at the University of Minnesota in 1982 and at the University of Wisconsin in 1984. Faculty member for the EMTP courses at the University of Minnesota Extension Program since July 1990. He has served as Chairman of the Industry Advisory Board for the University of Minnesota Center for Electric Energy. He has served on a National Academy of Sciences Panel on the National Geomagnetic Initiative. In March 1997, he was invited by the Presidents Commission on Critical Infrastructure Protection to brief the Commission on the "The Impact of Space Weather on Power Systems and their Operation." He is also a member of the Organizing Committee for the NATO Advanced Science Institutes Conference on Space Weather Hazards being held in June 2000 in Crete. Mr. Kappenman has also served as a member of the Science Advisory Panel in July 2000 to the NOAA Space Environment Center. He was on the Scientific Organizing Committee of the NATO Advanced Research Workshop on Effects of Space Weather on Technology Infrastructure (ESPRIT) held in Rhodes in March 2003. He is a member of the Editorial Advisory Committee to the AGU *International Journal of Space Weather.* He is one of the founders and current Chairperson of the Commercial Space Weather Interest Group.

He has been an active researcher in power delivery technologies and his primary engineering contribution has been his research work on magnetic storms and their disruptive effects on electric power systems. He is leading a design team to develop forecasting and mitigation techniques. He has also been a collaborator with EPRI and Global Atmospherics on the development and application of the Fault Analysis and Lightning Location System that will allow economic Location-Centered mitigation of lightning to transmission networks, work for which he has been granted a U.S. Patent. He is also one holds a U.S. Patent for his design of this device. He has been a principle investigator on a number of EPRI research projects on these and other subjects.

Mr. Kappenman is one of the principle investigators under contract with the *Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP Commission).* The EMP Commission was established by Congress under the provisions of the Floyd D. Spence Defense Authorization Act of 2001, Public Law 106–398, Title XIV. The EMP Commission was chartered to conduct a study of the potential consequences of a high altitude nuclear detonation on the domestic and military infrastructure and to issue a report containing its findings and recommendations to the Congress, the Secretary of Defense, and the Director, FEMA.

Engineering, Scientific and Professional Societies

He is a Senior Member of the Institute of Electrical and Electronics Engineers and the Power Engineering Society, and has served as the Chairman of the Transmission and Distribution Committee (1994–1996). He is also a member of the following IEEE Working Groups: GIC and Power System Effects, Flexible AC Transmission, and Lightning Performance of Transmission Lines and Distribution Lines.

He is a member of the American Geophysics Union. Registered as Professional Engineer in the State of Minnesota, License #25100.

Honors and Awards

He is a recipient of the IEEE Walter Fee Outstanding Young Engineer Award. The Westinghouse Nikola Tesla Engineering Award, two IEEE PES Prize Paper Awards and twice awarded EPRI Innovator Awards.

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Metatech

Oct 27, 2003

The Honorable Vernon J. Ehlers, Chairman
Subcommittee on Environment, Technology, and Standards
U.S. House of Representatives
Committee on Science
Suite 2320, Rayburn House Office Building
Washington, DC 20515-6301

Re: Letter of Metatech Financial Disclosure

Dear Congressman Ehlers:

As requested under the rules of the House of Representatives, Metatech would like to disclose the following sources and amounts of federal funding from 2001 through 2003 that would be directly supporting of the National Oceanic and Atmospheric Administration. The following are Metatech business activities that we interpret would fall under these rules:

> 2002: $10,000. for work performed as Meeting Facilitator for NOAA-NESDIS Meeting on future NOAA Geostorms Program. Metatech anticipates invoicing of additional $4,000. in 2003 for conclusion of meeting report filing. Services provided under contract with Short & Associates in Chevy Chase, MD.
>
> 2003: $50,000. for work under NOAA Phase 1 SBIR, Contract # DG133R-03-CN-0049, an additional invoice of $25,000. is anticipated by Metatech in 2004 under contract terms for completion of Phase 1 effort.

As mentioned in prepared testimony Metatech is performing investigations of US electric power grid vulnerability for the EMP Commission which was established by Congress under the provisions of the Floyd D. Spence Defense Authorization Act of 2001, Public Law 106-398, Title XIV. This work is not associated with any NOAA activities.

Sincerely,

John G. Kappenman
Division Manager
Metatech – Applied Power Solutions Division

Metatech Corporation – Applied Power Solutions Division
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BIOGRAPHY FOR HENRY P. (HANK) KRAKOWSKI

Vice President—Corporate Safety, Security & Quality Assurance United Airlines

Named to this position in November 2001, Captain Krakowski is responsible for corporate Safety, Security and Quality Assurance. These responsibilities cover all flight, operational, computer and maintenance functions, including emergency response. His organization is based in Chicago and has both Safety, Security and QA personnel worldwide.

Hank joined United as a pilot in 1978 and has served as Director of Flight Crew Planning and most recently as Director—Flight Operations Control. He was in charge of Flight Operations at United's Operations Control Center on September 11th 2001. In addition to his officer duties Hank also flies the Boeing 737 out of O'Hare.

A native of Evanston, Illinois, Hank holds a Master's degree in Business & Management and a Bachelor's degree in mechanical engineering from St. Louis University. Hank has served as chairman of communications and national spokesman for the Air Line Pilots Association.

Active in numerous aspects of aviation, he is also a rated Flight Dispatcher and practicing Aircraft Mechanic. In addition to rebuilding two aircraft, Hank has been an airshow pilot with the Chicago based Lima Lima aerobatic demonstration flight team. He lives in Deerfield, IL.

Captain H.P. Krakowski
Vice President - Corporate Safety, Security & Quality Assurance

UNITED

October 29, 2003

Chairman of the House Committee:

This letter will confirm that neither I nor United Airlines receive federal funding to support the Space Environment Center in Boulder, Colorado.

Sincerely,

Captain Henry P. Krakowski

P.O. Box 66100, Chicago, Illinois 60666 • Location: Elk Grove Township, Illinois, on Route 62, one-half mile west of Route 83

BIOGRAPHY FOR ROBERT A. HEDINGER

Dr. Robert Hedinger, Executive Vice President at Loral Skynet, U.S.A, is responsible for Sales, Marketing and Client Services. He joined AT&T Bell Laboratories in 1978 as a Satellite Systems Engineer responsible for Satellite System Design, Satellite Transmission Planning, and International Technical Regulatory Matters. He led marketing and sales for AT&T SKYNET Satellite Services from 1991 to 1993. He led Business Development efforts for AT&T and subsequently for Loral SKYNET from 1993 through 2002. Since then he has been responsible for Sales, Marketing, and Client Services. Dr. Hedinger participated in ITU activities since 1980. He chaired the U.S. delegation to CCIR Study Group 4 for three years and participated as a U.S. delegate to three WRCs. He participated as Vice Chairman of U.S. Delegation to WARC ORB'88.

Dr. Hedinger received his Ph.D. in Physics from the University of Cincinnati, Cincinnati, Ohio in 1975.

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October 28, 2003

U.S. House of Representatives
Committee on Science
Suite 2320 Rayburn House Office Building
Washington, DC 20515-630

Dear: Mr. Chairperson

Please be advised that neither Loral Skynet nor I, Robert A. Hedinger receive Federal Grant.

Sincerely,

Appendix 2:

Additional Material for the Record

Two Geomagnetic Storms Hitting the Planet

Solar Activity That Can Disrupt Communications Could Last Into Sunday

By Kathy Sawyer
Washington Post Staff Writer
Saturday, October 25, 2003; Page A10

The sun is hitting Earth with a one-two punch.

One geomagnetic storm struck the planet yesterday, and another one is hard on its heels and arriving this afternoon, but a two-day advance warning by solar weather forecasters enabled electrical utilities, airlines and spacecraft managers to take protective actions.

As of late yesterday, no one had reported significant disruptions. The geomagnetic activity, which began about 11:30 a.m. Eastern time, probably reached its peak in the afternoon and could last into Sunday, forecasters said.

Paal Brekke, a lead scientist for the European/U.S. solar research satellite SOHO, reported late yesterday that several expeditions in the Himalayas, including a Mount Everest team, "have severe difficulties with their data communications since yesterday." He said there have also been problems with expected updates from 16 rowing teams in the Atlantic. The teams left the Canary Islands on Sunday, and "only two have reported in since." They have reported the same data connection problems with their Iridium satellite phones as the Himalaya expeditions have with their satellite communications, Brekke said.

Scientists categorized the storm intensity as "modest to strong," with a rating of G-3 on a scale that goes to G-5.

Since last Sunday, forecasters at the National Oceanic and Atmospheric Administration's Space Environment Center in Boulder, Colo., have watched as one of the largest sunspot clusters in several years -- now about 10 times the size of Earth -- developed rapidly.

At 3 a.m. Eastern time Wednesday, the cluster of sunspots produced an explosive release of gas and charged particles known as a coronal mass ejection. Another soon followed, the scientists said, and both of these solar "burps" were aimed at Earth.

The sunspot cluster that triggered the ejections was "the fourth-largest sunspot region of this solar cycle," said forecaster Larry Combs of the space environment center, in a telephone interview. The activity is unusual, because it is occurring late in the approximately 11-year cycle of sunspot activity, he said. The cycle presumably reached its maximum in 2000.

"It's kind of like seeing a hurricane in November," he said. "The season's still there, but it's right at the end. And here's this hurricane that's in the moderate to strong category."

Sunspots are regions of intense magnetic fields, where the field lines twist and intertwine and can suddenly snap in a violent release of energy. Before Saturday, the space weather team had seen low solar activity and an almost "spotless" sun for a week.

The storm could trigger northern lights that would visible as far south as Oregon and Illinois, the scientists said.

In addition to the geomagnetic effects, the sunspots also produced flares -- bursts of energy -- that have caused radio blackouts affecting some aircraft, Combs said. Those could continue for another week or two.

Scientists have only recently developed the tools, including NASA spacecraft, and the know-how to forecast Earth-bound sun storms, enabling power companies and other customers to take precautions.

This week's performance "is a mark of how skilled the Space Environment Center of NOAA has become," said solar scientist Craig DeForest of the Southwest Research Institute.

"We're starting to see space weather predictions be not only useful but reliable."

Cloud of solar gas strikes our planet

Night skies may light up with auroras

By Marsha Walton
CNN

(CNN) --Airline navigation systems and satellite phones are feeling the effects of unexpectedly turbulent solar weather, but no widespread problems were reported Friday when a cloud of superheated gases reached Earth's upper atmosphere.

Scientists tracking heightened solar activity in recent days reported some commercial airlines have had to make adjustments to their high-frequency communications, or in some cases switch to alternate satellite systems.

"The first thing we notice in these storms is the X-rays, which travel at the speed of light and can cause radio blackouts," said Larry Combs, a space weather forecaster for the National Oceanic and Atmospheric Administration's Space Environment Center in Boulder, Colorado.

Several Himalayan expeditions using satellite phones have also had interference with their communications due to the X-rays, he said.

The X-rays were associated with strong solar disturbances this week, in particular a coronal mass ejection (CME) on Wednesday that sent a stream of energized particles in the direction of our planet.

X-rays reach Earth in a matter of minutes, but CME clouds take anywhere from two to four days. This one began arriving Friday morning, hours earlier than first predicted by space forecasters.

"It's not anything you can see, but it is something our instruments can track," Combs said.

Electrical grids, satellites and pagers and cell phones that rely on orbiting spacecraft can sometimes be affected by CMEs. In 2000, a solar blast briefly knocked out or created steering problems for several orbiting spacecraft.

And in 1989, one zapped the main electrical utility in Quebec, Canada, plunging millions into darkness for hours and costing billions of dollars to fix.

But many electrical systems on Earth and in orbit now have protective systems designed to minimize or prevent damage. And space weather experts like Combs think that this CME storm, classified a moderate 3 on a scale of 1 to 5, will not create major problems.

"After the next 24 hours it may start slowing down," Combs said.

But the sun is in an unexpected phase of energetic activity and could generate more X-rays, bursts or solar storms in the coming weeks, space weather forecasters caution. Sporadic high-frequency radio blackouts are likely to continue, Combs said.

While not as dangerous as a class 5 storm, what makes this one so unexpected is that it comes three years after the peak of an 11-year cycle of solar activity. Combs likens it to a hurricane on the last day of hurricane season.

And like hurricanes, they constantly change in intensity, making predictions a difficult challenge.

"Like anything in nature, sometimes they don't act like we expect them to," Combs said.

The solar stream erupted from a cluster of sunspots on the surface of the sun. The giant dark patch, known as sunspot group 10484, has grown to the size of Jupiter in recent days and has migrated across the face of the sun to a position where it now faces Earth.

Such magnetic storms can also produce spectacular nocturnal displays of the northern lights; NASA's Space Weather Web site is predicting that nighttime auroras could be visible as far south as Oregon and Illinois.

-- CNN.com's Richard Stenger contributed to this report

DIGITALGLOBE ORBIMAGE GLOBAL IMAGING INFORMATION SPACE IMAGING

October 22, 2003

The Honorable Vernon Ehlers, Chairman
U.S. House Science Committee
Subcommittee on Environment, Technology and Standards
Washington, DC 20515

Reference: NOAA Space Environment Center

Dear Chairman Ehlers:

As Chief Executive Officers of the U.S. commercial satellite imaging industry, we are writing to express our support for the Space Environment Center of the National Oceanic and Atmospheric Administration in Colorado. This facility provides critically important service to our companies, which, like all space-based operations, are significantly impacted by the rise and fall of solar storms.

Suggestions that have been made to move the monitoring of solar storms to other federal agencies such as NASA or the U.S. Air Force ignore the reality that neither of them are appropriate, nor prepared for executing this responsibility. It is our concern that making such a transfer of responsibility would serve only to delay or even eliminate this vitally important work.

Despite recent Congressional cuts to the Center's budget, we nevertheless firmly believe that the $8.3 million funding called for in the President's FY04 budget request is money well spent. Therefore, we respectfully urge your Subcommittee to continue to fully support the Space Environment Center.

Sincerely,

Herbert F. Satterlee, III
Chairman and CEO
DigitalGlobe, Inc.

Matthew O'Connell
President and CEO
ORBIMAGE

Robert Z. Dalal
CEO
Space Imaging, Inc.

Cc: Eric Webster, Majority Staff

AMERICAN METEOROLOGICAL SOCIETY
HEADQUARTERS: 45 BEACON STREET, BOSTON, MASSACHUSETTS 02108-3693 U.S.A.
WASHINGTON, D.C. OFFICE 1120 G STREET, N.W. SUITE 800 WASHINGTON, D.C. 20005
(202)737-9006 E-MAIL: ams@ametsoc.org FAX:(202) 737-9050

RONALD D. MCPHERSON, EXECUTIVE DIRECTOR

RICHARD E. HALLGREN, EXECUTIVE DIRECTOR EMERITUS
KENNETH C. SPLENGLER, EXECUTIVE DIRECTOR EMERITUS

October 23, 2003

The Honorable Vernon J. Ehlers
Chairman, Environment, Technology, and Standards Subcommittee
Committee on Science
U.S. House of Representatives
2320 Rayburn House Office Building
Washington DC 20515-6301

The Honorable Mark Udall
Ranking Member, Environment, Technology, and Standards Subcommittee
Committee on Science
U.S. House of Representatives
2320 Rayburn House Office Building
Washington DC 20515-6301

Dear Chairman Ehlers and Ranking Member Udall,

I am writing to address the current budget constraints facing the NOAA Space Environment Center (SEC) as well as the importance of its services. As the significance of space weather services increases, it is of great concern that the SEC may be forced to drastically reduce their vital and unique services or even disappear.

As former Director of NOAA's National Centers for Environmental Prediction (which includes SEC) from 1990 until 1998, I was aware of the critical products and services being provided by SEC to the commercial vendor community and the satellite, communication, electric power, and aviation industries. Now, as Executive Director of the American Meteorological Society, a scientific and professional Society that represents over 11,000 individuals and institutions in the science and services in meteorology and related fields, I have noticed an increasing interest in space weather applications among our members. As a result, the AMS is holding its first Space Weather Symposium at our Annual Meeting in January 2004. There are many similarities between meteorology and space weather services, including how they are disseminated and the sectors they impact. Because of the growing importance of space weather applications, we expect this year's Symposium to be a success and recognize the great contributions of SEC, the Nation's official source of space weather alerts and warnings.

Space weather can have many social and economic impacts, and forecasting space weather events can help users reduce or mitigate their risk. According to SEC, some specific economic impacts of space weather include:

- NASA uses SEC data to protect the $1 billion arm on the International Space Station;
- Underwriters of space assets attribute $500 million in claims from 1994-1999 that were caused, or contributed to, by space weather;
- FAA requires dispatchers to take into consideration Radiation Exposure of Air Carrier for each dispatched polar flight and to divert polar flights based on SEC solar radiation alerts if air traffic control communication is compromised; and
- Society is becoming more reliant on GPS, including future emergency services. A 1% gain in continuity and availability of GPS would be worth $180M per year.

NOAA's SEC provides unique services that include continually monitoring and forecasting Earth's space environment; providing accurate, reliable, and useful solar-terrestrial information; conducting and leading research and development programs to understand the environment and to improve services; and fostering the space weather services industry.

The AMS is concerned that in the pending House and Senate FY 2004 Commerce, Justice and State appropriations bills, SEC funding levels are below the Administration's request. The pending Senate Appropriations Committee report includes the suggestion that the U.S. Air Force or NASA should take on the duties of predicting space weather. NASA is not an operational agency and the U.S. Air Force has a strict military -- not civilian -- mission. Just as it makes sense for the National Weather Service to be in NOAA, it makes sense for the SEC to remain in NOAA.

The implications of closure or reduced activities of NOAA's SEC to the government and private sector would be a grave disservice to our Nation. There are many who depend on SEC services, including the U.S. power grid infrastructure, airline industry, NASA human space flight activities, DOT use of GPS, satellite launch and operations, U.S. Air Force operational support, and commercial providers of value-added space weather services.

We are concerned with the diminishing budget for SEC, as its significance is expanding. We are convinced that unless the appropriation for SEC is restored to the level of the President's FY04 Budget Request ($8.3 million) the Nation's civilian space weather service is in trouble.

You or your staff should feel free to call at any time to get in touch with me in connection with our support for SEC. As the AMS begins to embrace and integrate space weather into the activities of our Society, we are enthusiastic about these endeavors and remain major supporters of SEC.

Sincerely,

Ronald D. McPherson
Executive Director

cc: Amy Carroll
Jean Fruci
Genene Fisher (AMS)
Doug Stone (AMS)

October 23, 2003

Chairman Vernon Ehlers
Subcommittee on Environment, Technology and Standards
Committee on Science
U.S. House of Representatives
Washington, DC 20515

Chairman Ehlers;

The Satellite Industry Association (SIA)[1], the trade association representing commercial satellite service providers, operators, manufacturers, and launch vehicle services companies, is extremely concerned about the budget for the National Oceanic and Atmospheric Administration's (NOAA) Space Environment Center (SEC) and the decision by Congress to substantially reduce or eliminate its funding in the FY 2004 Commerce, Justice, State Appropriations bill (H.R. 2799, S.1585).

The SEC provides vital, real-time alerts and forecasts of space weather that are invaluable to the commercial satellite industry and its customers throughout the United States and the rest of the developed and developing world. Given the critical role that commercial satellites play in our nation's communications network and, as a result, in our national security, the elimination or the substantial reduction of the space weather services provided by the SEC would create an increased risk to the American public.

It is important to note that the SEC's highly reliable, real-time forecasting and rapid alert services are not otherwise available to commercial satellite operators, manufacturers and launch service providers from another source. As a result, the commercial satellite industry is dependent upon the information provided by the SEC. SEC staff understands the real-time operations needs of commercial satellite operators and consistently provides high quality, quick and professional support.

The real-time space weather forecasts provided by the SEC are critical to commercial satellite industry because they enable pro-active actions to be taken to avoid or minimize outages, safety issues or damages caused by space weather events.

For example, SEC forecasts enable satellite operators to make adjustments to operating procedures and changes to staffing levels in advance of severe space weather conditions. The SEC's continuous information, timely alerts of solar storms, and research to develop more accurate space weather forecasting are instrumental in the proper planning by satellite operators for the hazards of space weather.

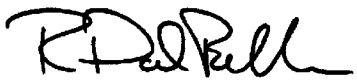
[1] SIA's members include The Boeing Company; Globalstar, L.P.; Hughes Network Systems; ICO Global Telecommunications; Intelsat; Iridium Satellite LLC, Lockheed Martin Corp.; Loral Space & Communications Ltd.; Mobile Satellite Ventures; Northrop Grumman Corporation; PanAmSat Corporation; SES-Americom, Inmarsat; New Skies Satellites; and Verestar. SIA Affiliated Members include The California Space Authority; Compass Rose International; and Futron Corporation. For more information on SIA, please visit the association's web site at www.sia.org.

225 Reinekers Lane, Suite 600 • Alexandria, VA 22314 • Phone 703 739-8358 • Fax 703 549-9186

I strongly urge you to support the $8.3 million of funding for the SEC as requested by the President or, at a minimum, the House-passed level of $5.2 million in the final FY 2004 Commerce, Justice, State Appropriations bill.

I appreciate your attention to this critical matter for the entire satellite industry.

Sincerely,



Richard DalBello
President, SIA

Aram M. Mika
Vice President, Advanced Technology Center
Lockheed Martin Space Systems Company
3251 Hanover Street Palo Alto, CA 94304-1191

LOCKHEED MARTIN

The Honorable Vernon J. Ehlers
Chairman - Environment, Technology & Standards Subcommittee
House Committee on Science
2319 Rayburn House Office Building
Washington, DC 20515

October 27, 2003

Dear Chairman Ehlers:

Thank you for the opportunity to present Lockheed Martin views on space weather forecasting and the importance of NOAA's Space Environment Center (SEC).

Lockheed Martin strongly urges the continuation of funding for the Space Environment Center in Boulder, CO at the Administration's requested level of $8.3M. Further, we believe that an increased capability in space weather forecasting is urgently required, and even recommend that this funding level be increased to meet the growing need for this type of service.

The continued availability of timely, accurate, and well-characterized space-weather forecasts is essential to our national security, communications, and commerce. Our ability to maintain and operate satellite systems, react appropriately to on-orbit anomalies, and design the next generation of manned and robotic space systems would be placed at significant risk if the source of the data and forecasts were interrupted. Accordingly, Lockheed Martin believes it is in our national interest to have a centralized repository of space weather expertise and data that can provide forecasts of the space environment and continually work to improve their fidelity and broaden their applications.

The U.S. has billions of dollars invested in commercial, civil, and military assets in space. Consequently, it is important to understand the environment in which these assets are operating, and to forecast what will be happening to that environment at least several days in advance. The SEC has provided this function very successfully for many years, and is considered to be a world leader in space weather forecasting. Creation of an entirely new organization to provide this service would take significantly larger initial and on-going investments than is represented by adequately funding the SEC and, potentially, would leave our national space investment dangerously vulnerable until an alternative capability is defined, implemented, and fully functional.

We respectfully request that you submit this letter with the accompanying statement as part of the record for your October 30 hearing on Space Weather Forecasting.

Sincerely yours,

Aram M. Mika

cc: Ranking Member Mark Udall

What Is Space Weather? Why Is It Important?

The Sun is a variable star. Its magnetic field varies on a time scale from seconds to decades. The origins of solar variability are still poorly understood, but it causes the Sun to produce vast explosions (flares and coronal mass ejections) and streams of ionized gas (the solar wind). The space environment, in which the entire Solar System exists, is controlled and modulated by these outpourings from the Sun. This variation in the space environment is called "space weather."

Fortunately, the Earth has a magnetic field and atmosphere that partially protects us from the daily changes in geospace conditions. However, some of these effects do make their way into the Earth system and can damage our spacecraft and endanger the health and safety our astronauts. Here on Earth, they can affect technologies vital to our civilization such as degrading communications, disrupting electrical power transmission, increasing corrosion rates in oil pipelines, increasing the radiation doses received by passengers and crew on some commercial airliners, and decreasing the accuracy of GPS.

The future of space exploration beyond the immediate Earth environment (i.e., beyond the protection of the Earth's natural shields) is intimately linked to the necessity of understanding space weather. If we are to send astronauts to Mars or set up a permanent base on the Moon, for example, then understanding these phenomena and being able to predict them will be vital to ensuring our explorers' safety.

Our Needs for Space Weather Data and Forecasts

Lockheed Martin Space Systems Company has a major stake in space weather. All of our space-related programs use space weather data in the planning, design, and operation of new orbital systems. Radiation dosage, communications quality, navigation and position measurement, surveillance, and mission life are concerns related to space weather in preparing reliable and successful space projects for the U.S. government. One of many possible examples: our Astronautics group (Denver, Colorado) uses SEC space weather forecasts to help scheduling the launches of Atlas and Titan rockets.

Our Advanced Technology Center in Palo Alto, California, works on a wide variety of space weather programs including building instruments for solar monitoring from the NOAA GOES spacecraft and the NASA Living With A Star (LWS) and Solar Terrestrial Probe programs. They research space weather phenomena originating from the Sun and model their direct effects in geospace. They have used the predictions from the NOAA SEC since the launch of the Solar Maximum Mission in 1980 to help optimize the scientific return from some of their solar missions.

Roles of Government, Academia and Industry in Space Weather

NSF, in collaboration with NOAA, DOD, NASA, and several other agencies, produced a study identifying the urgent need for a coordinated approach to space weather. This led to the National Space Weather Initiative. A part of this program was designed to improve the observations and research of space weather in the science community. This effort was spearheaded by NASA and NSF; which defined the outstanding theoretical and observational problems that need to be addressed. This led to the LWS program at NASA and comprehensive modeling projects at NSF.

Academia is important to the ongoing development of space weather because much of the ground-breaking research goes on at universities. While much of this research is of purely scientific interest, some of it leads directly to models and visualization techniques that are applicable to space weather forecasting. The NOAA SEC is responsible for being familiar with these advances and how they might best be applied to forecasting.

Because the NASA charter focuses on science rather than operational monitoring of phenomena like space weather, the task of gathering long-term space weather data fell to NOAA, hence the inclusion of space weather instruments on NPOESS and GOES–R. NOAA also takes the discoveries made by NASA and NSF research that are specifically relevant to space weather forecasting and turns them into the appropriate data products on which the space weather user community depends.

The SEC has acted as the interface between the space weather science and user communities. For example, they have organized a very successful series of annual meetings, Space Weather Week, which bring these different space weather communities (researchers, modelers, commercial suppliers, and users) together to help understand each other's capabilities and requirements. Without this vital role of the SEC, space weather forecasting would be many years behind where it is today.

Industry provides the capability to build the instruments, spacecraft, and ground systems for NASA research programs and uses that experience to supply the nec-

essary high-reliability monitoring systems for NOAA. The aerospace industry is also one of the many users of NOAA's space weather products.

Other government agencies (e.g., DOD, FAA, and DOE) are major users of NOAA space weather forecasts. They help define the observational requirements and data products that they want from the SEC. There is a marked rise in the number of companies whose business can be affected by space weather; these include the increase in commercial usage of GPS, cell phones, and the need for power grids to run nearer to capacity limits. This upsurge in the need for space weather products has resulted in a growing number of small businesses from all over the United States that provide space weather products specifically tailored to single-end-user needs. These companies rely entirely on the data and forecasts from the SEC.

Future Applications of Space Weather

The continuity and fidelity of the current space weather data and forecasting capabilities provided by NOAA SEC is vital. We should also consider what is needed in the future. Our investment and reliance on space technology are growing, and we need to respond to this by increasing our capability to forecast the operational environment of these ever more sophisticated and expensive space assets. To keep pace with these advances and new priorities, we believe that the SEC needs to grow steadily over the next few years.

Recently there has been increasing scientific interest in the potential link between space weather effects and climate change. It has been estimated that 30 to 50 percent of the recent climate change could be attributable to changes in the Sun. If this link is demonstrated to exist, as many scientists think it will, and the mechanisms are understood so that the space weather input to our climate can be modeled to accurately predict future climate change, then the solar and geospace data, processed and archived by NOAA, will be of huge economic importance to the Nation's long-term planning of water and land usage. Consequently, we cannot afford to lose or disperse the core of space weather expertise currently resident at the SEC in Boulder, Colorado.

Conclusions

The stage of development of space weather at present is very similar to that of meteorological forecasting more than 40 years ago. The data are sparse and incomplete, and the forecasts are not as accurate in the long-term as some of the users would like. The increase in data acquisition capability represented by the new NPOESS and GOES–R space weather instruments, plus the influx of new data from the current GOES Solar X-ray Imager series, will result in a significant increase in our capability to forecast space weather effects more accurately over a longer period. To take full advantage of this upsurge in space weather data and demand for more forecast products, we need a growing capability at the NOAA SEC, not a reduced one.

SES AMERICOM
An SES GLOBAL Company

Dean A. Olmstead
President & CEO

October 27, 2003

The Honorable Vernon Ehlers
House of Representatives
2319 Rayburn Building
Washington, D.C. 20515

Dear Mr. Ehlers:

SES Americom, Inc. ("SES Americom") is a fixed satellite service provider with more than 250 employees that is headquartered in Princeton, New Jersey. SES Americom offers services to customers via 16 satellites licensed by the Federal Communications Commission and we have been in operation for nearly 30 years. Our customers include the U.S. Government, broadcasters, cable programmers, corporations, direct-to-home service providers, internet service providers, and more. These customers use our satellites to distribute voice, video and data services for use by private networks or the U.S. consumer.

SES Americom has serious concerns regarding the current plans of Congress to severely cut or eliminate the budget for the Space Environment Center ("SEC") of the Department of Commerce. As you know, the FY 2004 House Commerce, Justice, State Appropriations bill, H.R. 2799, as passed in July, substantially reduces the SEC budget to $5.2 million, while the Senate counterpart, S. 1585, eliminates all funding for the SEC. SES Americom believes that the loss or reduction of the space weather services provided by the SEC would create an increased risk of interruption of services for our customers and to the health and safety of our satellite fleet.

The SEC provides real-time alerts and forecasts of space weather that are invaluable to commercial communications satellite operators. The SEC's highly experienced forecasting and rapid alert services are not otherwise available to commercial satellite operators. The SEC is the national and world center of space weather information, forecasting and alerts for commercial satellite operators. The SEC staff understands the real-time operations needs of commercial satellite operators and consistently provides high quality, quick and professional support.

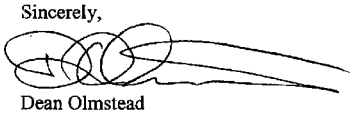
SES Americom, Inc. | Four Research Way | Princeton | NJ 08540 | USA | tel (1) 609-987-4100 | fax (1) 609-987-4318 | dean.olmstead@ses-americom.com | www.ses-americom.com

Space weather forecasts are important to commercial satellite operators because high-energy electron, proton or x-ray events can cause serious satellite outages or damage. SES Americom's spacecraft operations staff uses the SEC's space weather forecasts on a daily basis. The information provided by the SEC enables our staff to take appropriate actions to maintain optimal availability of service and safety of our fleet. While the SEC does not eliminate the hazards of spacecraft operations, its continuous information, timely alerts of solar storms, and research to develop more accurate space weather forecasting are needed by SES Americom to properly plan for and cope with the hazards of space weather.

Vital national communications links are provided via SES Americom satellites. I believe that adequate funding of the SEC is tantamount to an investment in the safety and security of the U.S. Government's telecommunications system and the entire nation's communications network. I strongly urge you to support the $8.3 million of funding of the SEC as requested by the President, or, at a minimum, the House-passed level of $5.2 million in the final FY 2004 Commerce, Justice, State Appropriations bill.

I appreciate your attention to this critical matter to our company and to the commercial satellite industry.

Sincerely,



Dean Olmstead

Shampaine, Adam

From: davedancesco@plbb.net
Sent: Wednesday, October 29, 2003 10:52 AM
To: Shampaine, Adam
Subject: Space Weather Vendor

Letter

Dear Mr. Shampaine,

I urge you to support keeping the NOAA Space Environment Center. I am the chief engineer for a new small space weather company (Space Environment Technologies), and have over 20 years experience at NOAA/SEC.

The importance of space weather to our customers has recently increased significantly. Our companies livelyhood depends on timely and accurate data streams from SEC, and a degradation in those current and planned data streams would adversely affect our company and our customers.

Our earths atmosphere includes it's space environment, our society is affected by space weather as much as it is climate. The inclusion of SEC

in NOAA is clearly is within NOAA's mission. Operational forecasting should not be done at NASA because of their research and development mission. Forecast at the Air Force Space Weather Command is limited in scale and mission, and not suitable for services intended for the international public.

Sincerely,

S. Dave Bouwer
Chief Engineer, Space Environment Technologies

641 Eldorado Blvd., unit 835
Broomfield, CO 80021
303-635-8113

PREPARED STATEMENT OF DR. W. KENT TOBISKA

PRESIDENT AND CHIEF SCIENTIST
SPACE ENVIRONMENT TECHNOLOGIES
1676 PALISADES DRIVE
PACIFIC PALISADES, CA 90272–2111

The shorter-term variable impact of the Sun's photons, solar wind particles, and interplanetary magnetic field upon the Earth's environment that can adversely affect technological systems is colloquially known as space weather. It includes, for example, the effects of solar coronal mass ejections, solar flares and irradiances, solar and galactic energetic particles, as well as the solar wind, all of which affect Earth's magnetospheric particles and fields, geomagnetic and electrodynamical conditions, radiation belts, aurorae, ionosphere, and the neutral thermosphere and mesosphere.

The U.S. activity to understand, then mitigate, space weather risks is programmatically directed by the interagency National Space Weather Program (NSWP) and summarized in its NSWP Implementation Plan [2000]. That document describes a goal to improve our understanding of the physics underlying space weather and its effects upon terrestrial systems. A major step toward achievement of that goal is the ongoing development of operational space weather systems which link models and data to provide a seamless energy-effect characterization from the Sun to the Earth. The NOAA Space Environment Center is the key agency providing the raw information necessary for inputs into these systems and the continued support by NOAA SEC to space weather users is of critical importance in our technology-based society.

In relation to space weather's effects upon the ionosphere, there are challenges to space- and ground-systems that result from electric field disturbances, irregularities, and scintillation. Space and ground operational systems that are affected by ionospheric space weather include telecommunications, Global Positioning System (GPS) navigation, and radar surveillance. As an example, solar coronal mass ejections produce highly variable and energetic particles embedded in the solar wind while large solar flares produce elevated fluxes of ultraviolet (UV) and extreme ultraviolet (EUV) photons. Both sources can be a major cause of terrestrial ionospheric perturbations at low- and high-latitudes. They drive the ionosphere to unstable states resulting in the emergence of irregularities and rapid total electron content (TEC) changes.

Trans-ionospheric radio communications and GPS navigation systems are particularly affected by these irregularities. The ionosphere's ability to reflect high frequency (HF) radio signals is affected and conditions are created where HF radio propagation is not feasible when signal amplitude and phase scintillations are degraded. For GPS navigation systems users in perturbed ionospheric regions, the timing of GPS signals becomes significantly and adversely degraded, translating directly into location inaccuracy and even signal unavailability.

Ionospheric perturbed conditions can be recognized and specified in real-time or predicted through linkages of models and data streams such as those provided by NOAA SEC. Linked systems must be based upon multi-spectral observations of the Sun, solar wind measurements by satellites between the Earth and Sun, as well as by measurements from radar and GPS/TEC networks. Models of the solar wind, solar irradiances, the neutral thermosphere, thermospheric winds, joule heating, particle precipitation, substorms, the electric field, and the ionosphere provide climatological estimates of non-measured present and predicted parameters. Data provided by NOAA SEC are continuously used by these models.

Space Environment Technologies, a company that provides advanced space weather products and services for government and aerospace customers, supports NOAA Space Environment Center in a common effort to develop operational ionospheric forecast systems that will detect and predict the conditions leading to dynamic ionospheric changes. Such systems will provide global-to-local specifications of recent history, current epoch, and 72-hour forecast ionospheric and neutral density profiles, TEC, plasma drifts, neutral winds, and temperatures. Geophysical changes will be captured and/or predicted (modeled) at their relevant time scales using data assimilation techniques. Linked physics-based and empirical models that will provide thermospheric, solar, electric field, particle, and magnetic field parameters will enable reliable forecasts and will mitigate risks from space weather to our technological systems.

ELECTRIFY THE WORLD

EPRI

CLARK W. GELLINGS, P.E.
Vice President
Power Delivery and Markets

October 31, 2003

Chairman Vernon Ehlers and Ranking Member Mark Udall
Subcommittee on Environment, Technology and Standards
Committee on Science
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Ehlers and Ranking Member Udall:

This is a request that the attached comments be included in the record for the subcommittee's hearing entitled: What is Space Weather and Who Should Forecast It?" which was held on Thursday, October 30, 2003 at 10:00am.

The Electric Power Research Institute (EPRI) was formed thirty years ago as the collaborative research and development arm of the electric utility industry, both public and private. We are organized as a non-profit, tax-exempt institute for the public good. My colleagues and I manage projects on behalf of the vast majority of the power produced and delivered in the United States. Because of our close involvement in utility matters and practices, we can supply useful information about current practices.

On behalf of EPRI and its members, we support the continued operation and funding for the Space Environment Center. The attached statement describes the importance of the Center to the electric utility industry.

Sincerely;

Attachment: as stated

Cc: Ray Lings
T.J. Glauthier

3412 Hillview Avenue | Palo Alto CA 94304-1395 USA | 650.855.2610 | Fax 650.855.8575 | cgelling@epri.com

COMMENTS OF THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI)

EPRI is a non-profit corporation formed by U.S. electric utilities in 1972 as the Electric Power Research Institute to manage a national, public/private collaborative research program on behalf of EPRI members, their customers, and society. Today, EPRI has over 1,000 members consisting of government-owned utilities (both federal and non-federal), rural electric cooperative associations, investor-owned utilities, Independent and Affiliated Transmissions Companies (ITC and ATC), Independent System Operators (ISOs), and Regional Transmission Operators (RTOs), foreign (international) utilities, independent power producers, and governmental agencies engaged in funding electricity-related research and development.

EPRI has gained a worldwide reputation for excellence and credibility in scientific research and technology development related to electricity. As a tax-exempt scientific organization under Internal Revenue Code Section 501 (c) (3), EPRI makes its research results available through its technology transfer program, including publication of reports, licensing of intellectual property, and sponsoring seminars and conferences.

INTRODUCTION

Moderate and local disturbances in the power grid as a result of solar storms were seen from time to time, but was not fully understood that the possible damage could be serious until the storm of March 31, 1989. As a result of this storm, the Province of Quebec suffered a complete blackout and major equipment damage occurred in the northern United States. Since that event, the industry has been aware of the potential harm and has become more careful about noting Space Environment Center (SEC) alerts and responding to them.

The Northeast Blackout of August 14, 2003 was a reminder that the power grid is dynamic and that the necessary operational balance must be maintained with some care. Solar storms represent another disturbing influence which can unsettle the system if we are not careful. The alerts of the Space Environment Center provide critical information used by many utilities to gauge how to plan their operations during times of expected stress.

How likely is it that we will see a repeat storm of severity equal to that of March 13, 1989? We have since experienced a half of a sunspot cycle and not seen a comparable storm impact the earth. On the other hand there are compelling reasons to expect that our system is becoming more susceptible, rather than less, to the same disturbance. Several trends combine to this so:

> Deregulation has increased the purchase of power from more remote locations and thereby increased the long distance flows of power over the grid. Longer lines are more vulnerable to disruption from solar storms.
>
> The relative loading of lines and transformers compared with their ratings have increased as load has grown faster than new installations. Equipment used near its limits of temperature and magnetic flux can be more easily pushed into failure from solar storms.
>
> The use of microprocessors in electric energy consuming devices and appliances is rising dramatically. As a result, US business and industry is increasingly demanding more reliable, digital quality electrical supply. Microprocessor-based devices are more prone to disturbance and to misinterpretation of noisy signals that are likely to result from the effects of solar storms on the power grid.

Against the unknown probability of a recurrence (admittedly not a high probability) there must be balanced the projected cost of a widespread outage. This cost could be very high indeed. In the United States, the region of highest risk runs form the Canadian border down to the middle of the country. Because the Magnetic North Pole is displaced somewhat towards the eastern U.S., the region of highest risk does not extend as far south into California as it does into Virginia. By coincidence, the recent Mid-West/Northeast Blackout of August 14 and 15, 2003 can serve as a reasonable model of what might happen from the recurrence of a high magnitude solar storm in the eastern U.S.

We value the alerts issued by the Center to our industry. Many utilities curtail elective maintenance operations and take steps to distribute their generation more evenly on the basis of these alerts. Several utilities have combined under the leadership of EPRI to pool readings of solar induced currents in real time so we can better assess the current status of any ongoing event.

We value the studies the Center makes of the solar wind and the evidence and data it is accumulating that will one day give us a much better understanding of phenomena we only observe today. It would be of great value if one day the Center

was able to predict further into the future and with more certainty what to expect from the solar flows.

We value the studies of solar phenomena, the drivers of all the effects we experience. Understanding here may be further away, but could be even more valuable for predicting releases many days into the future.

It is not clear that any other public or private organizations have the budget or interest to pursue such long-term matters. The solar phenomena influence industries as diverse as communications, oil and gas pipelines and the electric power industry. The U.S. military has an interest in the matter of solar disturbances, which can disrupt GPD systems and indirectly impact them through loss of electric power.

NCAR

National Center for
Atmospheric Research

TIMOTHY L. KILLEEN
Director

P. O. Box 3000, Boulder, CO 803007-3000 USA
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killeen@ucar.edu www.ncar.ucar.edu

October 31, 2003

The Honorable Vernon J. Ehlers, Chairman
and The Honorable Mark Udall, Ranking Member
Subcommittee on Environment, Technology and Standards
House Committee on Science
2319 Rayburn House Office Building
Washington, DC 20515

Sent Electronically 10-31-03

Dear Chairman Ehlers and Ranking Member Udall:

I would like to submit, for the Congressional Record, the attached written testimony regarding the Subcommittee on Environment, Technology and Standards hearing, *What is the Forecast for the Future of Space Weather Prediction?*, held on October 30, 2003.

I would like to thank you and your colleagues for the attention being paid by the Committee to this important topic.

Sincerely,

Timothy L. Killeen

Eric Webster
Amy Carroll
Jean Fruci
Jennifer Barrett

Enclosure

The National Center for Atmospheric Research
is operated by the
University Corporation for Atmospheric Research
under sponsorship of the
National Science Foundation

PREPARED STATEMENT OF TIMOTHY L. KILLEEN

DIRECTOR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

I wish to thank Chairman Ehlers, Ranking Member Udall, and Members of the Subcommittee on Environment, Technology and Standards for holding the October 30 Subcommittee hearing, *What Is Space Weather and Who Should Forecast It?* Space Weather is a relatively new, but critical area of scientific research and operations that may not be understood or appreciated by many in a manner that captures the field's importance to the Nation's security and technological preeminence in the world. You are doing the country a great service by examining the state of the science and recent questions that have been raised by Congress about who should forecast space weather and provide warnings about threats from solar storms. I write this not only from my position as director of the National Center for Atmospheric Research (NCAR), but as principal investigator of an instrument on the, (TIMED) satellite. A major goal of TIMED is to improve our ability to predict and understand Space Weather.

I would like to address the work and positioning of the Space Environment Center (SEC) of the National Oceanic and Atmospheric Administration (NOAA), the main topics of the October 30 hearing. I have experience working with the scientists of SEC and was quite concerned to see the FY 2004 marks and language in both the House and Senate NOAA bills regarding the Center. The President's request for SEC provided it with a $3 million increase over FY 2003. As I am sure you are well aware, the House mark eliminated this increase, keeping the account flat. Worse, the Senate zeroed SEC out and included the following language in the committee report: *The "Atmospheric" in NOAA does not extend to the astral. Absolutely no funds are provided for solar observation. Such activities are rightly the bailiwick of the National Aeronautics and Space Administration and the Air Force.*

The atmospheric sciences community is fully aware of the requirement in both the House and Senate bills to review NOAA research operations. Such a review will, I believe, strengthen those operations and provide long-term benefits to the country. However, the language of the Senate bill in particular seems to criticize research activities within NOAA across the board and single out SEC as an inappropriate NOAA function. This approach seems to me likely to be of significant harm to the Nation's scientific endeavors.

SEC has made many extraordinary basic and applied research contributions that have been described in detail by SEC Director Hildner in his testimony. These include the real-time monitoring and forecasting of solar events such as radiation storms that can damage satellites and electrical grids. The Center provides forecasts and real-time data that enable the prediction of solar effects on the Earth's magnetosphere, ionosphere, and upper atmosphere. These effects include enhancements of the radiation belts, ionospheric interference with communication and navigation systems, and changes in the orbits of satellites. SEC is the undisputed world leader in space weather forecasting, and its services are of significant value to commercial, military, and research endeavors conducted in near-Earth space.

In cooperation with the U.S. Air Force, SEC operates the Space Weather Operations Center, which serves as the national early warning center for space disturbances that can affect people and equipment working in the space environment. Research satellites such as the Hubble Space Telescope as well as communications and surveillance satellites are protected by the Center's activities, as are astronauts on the Space Station. Additional SEC activities include the prediction of solar influences on the Earth's magnetosphere, ionosphere and thermosphere. SEC predicts energetic particle fluxes in the Earth's ring current of geomagnetically trapped ions and electrons, ionospheric disturbances and their effect on radio communication, and thermospheric densities that affect satellite drag. The skill and knowledge to be able to provide these assessments are not easy to come by, taking years of experience to develop. Also taking much skill and experience to develop are effective ways in which to provide end users with information needed for operational purposes. SEC does an excellent job on both fronts.

The geophysical indices SEC provides are used by a wide number of scientific researchers, students, postdoctoral students, and the general public. They are employed in models of the upper atmosphere, ionosphere, and magnetosphere, and are important for operational studies. Disrupting SEC at this time would have a negative impact on studies involved with NSF-sponsored programs such as *Coupling, Energetics and Dynamics of Atmospheric Regions* (CEDAR), *Geospace Environment Modeling* (GEM), and *Solar, Heliospheric, and INterplanetary Environment* (SHINE), as well as satellite studies of NASA and the DOD.

Space weather basic and applied research at SEC provides critical support to the operational forecasting and data services. SEC maintains active collaborations with the National Center for Atmospheric Research, the University of Colorado, Boston University, and many other institutions engaged in the extensive and challenging endeavor of obtaining a full and detailed physical understanding of the processes that drive solar activity, solar particle and electromagnetic radiation, changes in the solar wind and magnetic field, and the response of the magnetosphere-ionosphere-thermosphere system to those changes. In particular, SEC is a national leader in developing numerical models of the solar wind and the ionosphere, and data assimilation techniques applied to the upper atmosphere. Research at SEC is of very high quality and, I believe, is an irreplaceable component of current multi-institutional projects to create the next generation of coupled Sun-to-Earth numerical modeling systems for space weather forecasting.

As stated above, language in the Senate budget for FY04 implies that SEC functions should be transferred to NASA or to the Department of Defense (DOD). I have close working knowledge of the programs of NASA and believe that it is an agency that is not equipped to provide support for continuous ("24×7") data and forecast services, having other priorities more critical to its core mission. Therefore, I do not believe that NASA would provide an appropriate home for SEC operational activities in the near-term. DOD could conceivably manage the operational arm, but would not be an appropriate home for the research activities conducted at SEC. In addition, DOD's primary responsibility is military defense of the Nation. In times of war or other military emergency, it is conceivable that DOD operations would be classified and would pertain only to military matters. In this situation, response to civilian concerns relating to solar geomagnetic and radiation storms would likely be of lower priority.

I am sure that you are aware of the recently released National Research Council (NRC) decadal study on research strategy in solar and space physics titled, *The Sun to the Earth—and Beyond.* In this document, the eminent members of eight Blue Ribbon panels, committees, and boards strongly endorse SEC and recommend throughout that NOAA, NASA, DOD, and the National Science Foundation collaborate to lead the military and civilian effort to continue and to expand solar and space research, research applications, the acquisition of real-time data, and technology development.

A recommendation on page 14 of the NRC report states that "NOAA should assume responsibility for the continuance of space-based measurement such as solar wind data. . ." This is a recommendation by numerous experts in the field. Absolutely nowhere in this document is there a recommendation that NOAA extricate itself from solar and space weather work because it is inappropriate to its mission. To the contrary, recommendations throughout elucidate the critical role that NOAA plays among the four involved agencies.

Though constrained by limited budgets SEC has done excellent work within NOAA and I believe it makes sense for it to continue to reside there. NOAA's mission reads in part, "To understand and predict changes in the Earth's environment. . .to meet our nation's economic, social, and environmental needs." The Sun makes life on Earth possible and causes tremendous environmental changes. To better understand the Sun's behavior is to better understand Earth's environment. To understand the threats of solar geomagnetic and radiation storms and warn of their possible impacts contributes to meeting our nation's economic, social, and environmental needs. In my opinion, SEC's work is an integral part of the NOAA mission.

I understand that NOAA leadership is considering the transfer of SEC (should it survive the FY 2004 Appropriations process) from the Office of Oceanic and Atmospheric Research (OAR) to the National Weather Service (NWS). Transfer of SEC to NWS could strengthen its operational mandate, and provide a programmatic environment appropriate to its national mission. I would have some concern, though, that the critical, basic research side of the Center could become undervalued within the overwhelmingly operational environment of NWS. The two sides of SEC are symbiotic and not readily separated without seriously compromising the forecasting side. As has been stated before, operations are only as strong as the research and research applications behind them. To diminish one is to weaken or cause stagnation in the other. I would like to urge the Committee to seek assurances from NOAA leadership that, if SEC is transferred from OAR to NWS, the research side of the laboratory will receive continued support within NWS, or will be maintained elsewhere within NOAH with a close working relationship to the operational side.

In closing, I would like to note that NOAA/SEC is the undisputed world leader in space weather forecasting. SEC has an effective balance of research and operational staff in the area of solar-terrestrial physics and an ideal scientific culture

for the purpose of forecasting. To create such a balance and culture at any other U.S. institution would be difficult, time-consuming, and expensive.

SEC could, in principle, be transferred to another agency, but that would require unnecessary expenditures, disruptions, and a short-term (if not long-term) downgrading in the quality of forecasting. Space weather forecasting is of immense importance to this technologically advanced nation; it should be carried out at NOAA, the culture of which supports forecasting with a strong scientific basis.

Mr. Chairman, in your leadership role with the Committee, and as a fellow physicist, I hope you will appreciate the value to the country of protecting SEC's research and operational role within NOAA, the importance of which was illustrated well during the very recent solar storms that erupted in the Earth's direction. I thank you and Mr. Udall for the opportunity to submit this written testimony and I appreciate your attention to this important matter.

Metatech

Sept 8, 2003

Mr. David Caldwell
National Weather Service
Mail Code W/NP, Room 100
5200 Auth Road
Camp Springs, MD. 20746-4304

Re: Letter of Support for Vital Services of the NOOA-Space Environment Center

Dear Mr. Caldwell:

Metatech would like to indicate it's support for the vital role and services that the NOAA-SEC provides to our nation and the national critical infrastructures that can be impacted by severe Space Weather events. Our company in particular works with the electric power industry in the US and around the world on the important threats that this critical infrastructure faces from geomagnetic storms. In the US for example, the PJM, the NY-ISO, ISO-NE and WECC pools all have operational procedures that they follow to attempt to increase security of their operations under adverse geomagnetic storm conditions and alerts provided by the SEC. Metatech works very closely with the SEC and uses much of the data and analysis that SEC provides as raw data inputs to further serve this important industry with the possible impacts that these storms could cause and how to better operationally prepare their systems for these storms.

In another example of the severity of threat that the power industry faces from the Space Environment, Metatech is currently performing analysis work for The Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP Commission). This commission was established by Congress under the provisions of the Floyd D. Spence Defense Authorization Act of 2001, Public Law 106-398, Title XIV. In addition to EMP, the Commissions effort also includes an assessment of power system vulnerability due to large geomagnetic storm events. While the Commission has not yet released it's findings (scheduled for Spring 2004), the analysis that Metatech has provided to the Commission indicates that the US power industry faces a high degree of space weather risk even in comparison to other terrestrial environment storms and that large geomagnetic storms can almost uniquely pose a risk of blackouts larger in size and geographic extent than the recent US Blackout of August 14, 2003. Of nearly equal concern is that these storms have the possibility of producing permanent equipment damage that can greatly impair the ability to provide rapid restoration should a large failure occur. This scenario presents the specter that many millions of people could be subjected to extended power system outages and impact even basic survival needs such as distribution of potable water and foods.

Metatech

As a member of the new AGU Space Weather Journal Editorial Advisory Board, I have been asked to provide the attached editorial opinion article for the Inaugural Edition of this Journal in October of this year, regarding the recent US Power Grid Blackout of August 14, 2003. Please find enclosed a copy of the draft article that I have submitted which draws some important parallels to the circumstances of August 14, 2003 and the threat posed to this same infrastructure due to Space Weather.

I would hope that you and other responsible managers at the Department of Commerce, NOAA and the NWS will do all that is possible to encourage the restoration of appropriate funding for the SEC so that they can continue to support the nation and its power industry Space Weather needs.

Sincerely,

John G. Kappenman
Division Manager
Metatech – Applied Power Solutions Division

Metatech Corporation – Applied Power Solutions Division
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Voice: (218)-727-2666 – FAX: (218)-727-2728
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2455 HAYWARD
ANN ARBOR, MICHIGAN 48109-2143

November 3, 2003

The Honorable Members
Subcommittee on Environment, Technology, and Standards
108th Congress
2320 Rayburn House Office Building
Washington, DC 20515

RE: October 30, 2003 - Subcommittee on Environment, Technology, and Standards Hearing on "What is Space Weather and Who Should Forecast It?"

Members of the Subcommittee,

We would like to submit the attached correspondence with the members of the Senate Appropriations Committee and Michigan Senators for inclusion in the record of the above-referenced Subcommittee Hearing. As stated in the attached letter, the elimination of all funding for NOAA's Space Environment Center in fiscal year 2004 will have an extremely deleterious effect on the Nation.

At the University of Michigan, we have a vigorous research program directed at various aspects of space weather phenomena, including a program to develop a high performance computer simulation of the environment from the solar surface to the Earth's upper atmosphere. We estimate that our annual research effort for space weather related research is about $2 million. We have worked closely with the scientific staff at the SEC to ensure that our research results may someday be suitable for transition to operational use by the SEC for the benefit of society.

The work conducted by and through the SEC is invaluable to the future of space weather research and forecasting. Closure of the SEC will create a shock to the morale of the space weather scientific community including the funding agencies that support this important research. We urge the subcommittee to support continued full funding for the SEC.

Respectfully yours,

Tamas I. Gombosi
Professor and Chair

C. Robert Clauer
Research Professor

November 11, 2003

Mr. Vernon Ehlers
Chairman
Subcommittee on Environment,
Technology and Standards
Committee on Science
U.S. House of Representatives
Washington, DC 20515

Mr. Mark Udall
Ranking Member
Subcommittee on Environment,
Technology and Standards
Committee on Science
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Ehlers and Mr. Udall:

On behalf of the Space Council of the Aerospace Industries Association, I applaud the efforts you are making to restore funding for NOAA's Space Environment Center in Boulder, Colorado. As your recent hearing highlighted, that center provides critical forecasting services to a wide range of government and private-sector users. It would be a tragic mistake to see the center closed.

The enclosed paper outlines our position more clearly. Please let me know if you need further details.

If AIA may ever be of help to you in gathering industry perspectives on other space issues, please do not hesitate to let me know.

Sincerely,

Bruce L. Mahone
Director, Space Policy

Aerospace Industries Association of America, Inc.
1000 Wilson Boulevard Arlington, VA 22209-3901 (703)358-1095 www.aia-aerospace.org

AIA
AEROSPACE INDUSTRIES ASSOCIATION

October 27, 2003

The Honorable Judd Gregg
Chairman, Subcommittee on Commerce, Justice and State
Committee on Appropriations
United States Senate
Washington, D.C. 20510

Dear Chairman Gregg:

On behalf of the Aerospace Industries Association of America (AIA), which represents more than 220 companies that employ nearly 700,000 manufacturing workers, I respectfully urge the Senate to recede to the House Appropriations Committee mark of $5.2 million for NOAA's Space Environment Center (SEC) should a conference committee convene in the near future.

As you know, the SEC jointly operates the Space Weather Operations Center with the U.S. Air Force to provide real-time national and international warnings that can affect personnel and equipment working in a space environment and on flights over polar routes. SEC data flow on a regular basis to users in the Pentagon, NASA and the FAA as well as airlines and electric utility and satellite operators. These data provide critical forecasts of potential geomagnetic and ionospheric storms that can damage satellite electronic systems; disrupt ground-to-air, ship-to-shore and U.S. government radio communications; or pose radiation hazards to flight crews and passengers. Similarly, the SEC issues magnetic storm alerts to ensure the protection of the nation's electrical grid. Public and private sector customers alike further rely on SEC forecasts to determine schedules for satellite launches and maintenance. They also monitor SEC notices for emergency notifications on whether broadcasting, ship and aircraft crews must activate secondary frequencies.

AIA member companies in both the space transportation and civil aviation sectors strongly believe that SEC products allow them to plan the use of their propulsion and communications systems to minimize serious solar or electromagnetic risks. The SEC therefore makes a direct contribution to the reliability of American air and space travel platforms, and for this reason, we would deeply appreciate your support for the House position.

Sincerely,

John W. Douglass
President and Chief Executive Officer

PREPARED STATEMENT OF BRUCE MAHONE

Space Weather Funding in Jeopardy

As a result of a Washington funding dispute, the Space Environment Center (SEC) in Boulder, Colorado, might have to close its doors in the coming months.

Funding for the Center has been reduced by the U.S. House of Representatives and cut entirely by the Senate. This could have a devastating impact on the U.S. airline industry, U.S. astronauts, the U.S. power distribution grid, worldwide navigation of all types, and U.S. military exercises.

The SEC is jointly operated by the Commerce Department's National Oceanographic and Atmospheric Administration (NOAA) and the U.S. Air Force.

Although other government entities collect data on space weather, no other facility serves as a focal point for aggregating and disseminating the full range of space weather information currently available. And no other office serves such a broad range of customers with its data—NASA, FAA, NOAA, DOD, and the private sector.

If the type of data provided by SEC were no longer available nationwide, some or all of the following effects could be expected:

Harmful radiation to airline passengers. Commercial airlines and high-altitude business jets flying polar routes during intense solar flares are subject to radiation doses as injurious to humans as the low-level radiation from a nuclear blast. This is the equivalent of 100 chest x-rays and would lead to increased cancer rates among crew and passengers. Without space weather information, aircraft operators do not know when to change direction to slower, yet safer non-polar routes.

Deadly radiation to astronauts. Astronauts venturing outside the Space Shuttle or International Space Station during intense solar activity are subject to dangerously high levels of radiation.

Loss of electrical power grids. For economic reasons, many portions of our nation's power grid regularly operate at peak capacity. If faced with a voltage spike induced by a magnetic storm, many nodes on the grid cannot handle the surge and would fail. When alerted that a magnetic storm is coming, however, grid operators can reduce the amount of electricity flowing through the grid, allowing "space" for the coming voltage spike and thus avoid system failure.

Critical navigational errors. Solar events and magnetic storms can interrupt or degrade navigation signals from Long Range Navigation (LORAN) systems and Global. Positioning Systems (GPS). This can lead to navigation system failures or, even worse, false position readings. Navigators notified of such intense space weather can switch to backup navigation systems, thus avoiding misdirected vehicles and potential crashes.

Military effects. Electromagnetic signals caused by solar emissions influence high frequency communications, satellite ultra-high frequency communications, and GPS navigation signals. They also increase interference or false returns to sunward and/or poleward looking radars. Those who track satellites and other objects in orbit can potentially lose their targets because of these changes in the atmosphere caused by space weather.

Some in Congress are concerned that NOAA should stick to its core mission of tracking weather within Earth's atmosphere and not concern itself with weather patterns in space. Space weather, however, does ultimately enter Earth's atmosphere and (as noted above) affects systems on the ground.

Others are concerned that SEC funding comes from a portion of NOAA's budget designated for scientific research rather than for operational forecasting. This is not, however, inconsistent with SEC's work. Forecasting space weather and using the forecasts in real time is still in its infancy. It is a field that has proved very helpful in numerous ways, but one that is still in need of extensive research.

The view of the aerospace industry is that the Space Environment Center is not "broken" so there is no reason to "fix" it by moving its function to NASA, DOD, or another agency. And curtailing the services provided by SEC is not an option, particularly considering the hazardous threat environment in which we find ourselves. Keeping our nation safe, secure, and economically viable requires every bit of critical information available. And a major component of that information is space weather.

AIA is taking an active role with its Space Council and legislative staff to ensure that SEC funding is restored. The amount of funding the office requires (roughly

$5–8 million per year) is very modest compared to the benefits received from the products it offers for the good of our nation.

Ball Aerospace & Technologies Corp.
2200 Clarendon Boulevard, Suite 1202, Arlington, VA 22201-3302 (703) 284-5400 FAX (703) 284-5449

November 19, 2003

Chairman Vernon Ehlers
Subcommittee on Environment, Technology and Standards
House Science Committee
2319 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Ehlers,

Ball Aerospace & Technologies Corp. requests the attached letter be included in the official record of the Subcommittee on Environment, Technology and Standards for the hearing entitled, "What is Space Weather and Who Should Forecast It?" held on Thursday, October 30, 2003.

Sincerely,

Carol Lane
Vice President, Washington DC Operations
Ball Aerospace & Technologies Corp.

Ball Aerospace & Technologies Corp.
10 Longs Peak Drive, Broomfield, CO 80021-2510
Reply to: P.O. Box 1235, Broomfield, CO 80038-1235

David L. Taylor
President and Chief Executive Officer
(303) 533-4100 FAX (303) 533-4111

November 18, 2003

The Honorable Judd Gregg (R-NH)
Chairman, Commerce-Justice-State Appropriations Subcommittee
United States Senate
Washington, DC 20510

The Honorable Ernest F. Hollings (D-SC)
Ranking Member, Commerce-Justice State Appropriations Subcommittee
United States Senate
Washington, DC 20510

The Honorable Frank R. Wolf (R-VA)
Chairman, Commerce-Justice-State Appropriations Subcommittee
United States House of Representatives
Washington, DC 20515

The Honorable Jose E. Serrano (D-NY)
Ranking Member, Commerce-Justice-State Appropriations Subcommittee
United States House of Representatives
Washington, DC 20515

Gentlemen:

As Chief Executive Officer of a U.S. aerospace company, I am writing to express my support for the Space Environment Center (SEC) of the National Oceanic and Atmospheric Administration (NOAA) in Boulder, Colorado. As a builder of space hardware, our company and our customers do rely upon the services provided by the center.

Space-based operations are significantly impacted by the rise and fall of solar storms. The SEC continually monitors space environment information, which is then used by spacecraft operators to assure critical commands are not issued during times of susceptibility to radiation effects. Data from NOAA monitoring instruments are used to characterize the total radiation environment, required by aerospace companies such as ours to determine levels of radiation shielding required for sensitive electronics. Real-time receipt of these data are used to support

National Aeronautics and Space Administration (NASA) launches, and to monitor and predict cancer-causing radiation levels that may be experienced by our nation's astronauts if proper avoidance measures are not taken.

Suggestions that have been made to move the monitoring of solar storms to other federal agencies, such as NASA or the U.S. Air Force (USAF), ignore the reality that neither agency is appropriate or prepared for executing this responsibility. NASA is a research agency; its mission does not expand to operational systems. NOAA and the USAF work together to monitor the space environment, and issue joint forecasts to their respective customers. The USAF, by its very focus on national security, is ideally suited to issues affecting classified systems. On the other hand, NOAA's role within the Department of Commerce makes it uniquely appropriate for issuing information to the commercial and non-classified sectors of our economy. I am concerned that transferring the SEC's responsibilities from NOAA to yet another agency would delay or even eliminate this vitally important work.

I recognize the difficult decisions you must make within the constraints of the budget. However, the health and effectiveness of the federal government's space-based assets, as well of those of the commercial aerospace industry, are reliant upon this center's services. The $8.3 million in FY2004 funding called for in the President's budget request is justified. Therefore, I respectfully request that the Commerce-Justice-State appropriations conferees restore the President's budget request for the Space Environment Center in the final FY2004 budget.

Sincerely,

Dave Taylor, President & CEO
Ball Aerospace & Technologies Corp.

October 22, 2003

U.S. Representative Vernon Ehlers, chairman
House Subcommittee on Science, Enviornment, Technology and Standards
2320 Rayburn House Office Building
Washington DC 20515

Dear Representative Ehlers:

My wife Cheryl (WY5H) and I as ham radio operators are extremely concerned about the severe cuts in the budget of the Space Environment Center, which is part of the National Oceanic and Atmospheric Administration (NOAA), and due for consideration during an October 30 hearing before the House Science' Committee's Subcommittee on Environment, Technology, and Standards. This agency, staffed jointly by NOAA and the U.S. Air Force and totally funded by NOAA, provides valuable space weather reports on solar and geomagnetic activity that can affect the ionosphere and in turn affect radio propagation, which is vitally important to ham radio operators in worldwide communications.

As you well know ham radio operators provide a volunteer communications service the the nation as exampled by the services provided during the search for Shuttle Columbia debris after that tragedy during reentry. Hams were able to provide communications linking all phases of the search, when Texas and Louisiana law enforcement agencies, and even NASA could not communicate. Besides just ham radio operators, the space weather forecasts and observations also assist NASA and other governmental agencies operating Earth satellites. Solar flares, which the center monitors and forecasts, can severely damage satellites and even shuttle communications unless proper precautions are made beforehand.

The current House budget cut the center's budget 40 percent and for FY 2004 another 40 percent cut is proposed, with the Senate version cutting out the center's appropriation altogether. The senate version also includes a rather cynical comment that "atmospheric" in NOAA's name doesn't extend to space, but someone is shortsighted and totally in error if they do not think that solar eruptions, flares, etc. play no part in Earth's weather.

We hope you as the subcommittee chairman will support funding for the Space Environment Center and please add our comments to the committee's record..

Sincerely,

Tom Anderson, WW5L
3505 Cliffwood Drive
Colleyville, Texas 76034
e-mail: WW5L@gte.net

cc: Dr. Michael Burgess, Texas Congressional District 26

Shampaine, Adam

From: Daniel Baker [Daniel.Baker@lasp.colorado.edu]
Sent: Wednesday, October 29, 2003 11:38 AM
To: Shampaine, Adam
Cc: baker@lasp.colorado.edu
Subject: NOAA Space Environment Center

Dear Mr. Shampaine,

I am writing to express my strongest possible support for the NOAA Space Environment Center here in Boulder, Colorado. If possible and appropriate,
I would like to ask that my statement be entered into the record as part of the testimony to be gathered for the Subcommittee on Environment, Technology, and Standards of the House Science Committee.

I am a practicing space scientist at the University of Colorado in Boulder.
My area of research is in space plasma physics and solar-terrestrial physics.
I am actively engaged in the study of space weather and its influence on human technology. I am a co-Director of the National Science Foundation's
Center for Integrated Space-weather Modeling (CISM). I also chair NASA's Living With A Star (LWS) Management and Operations Working Group. In all of these capacities, I see with great immediacy and clarity just how crucially important it is that the NOAA/SEC function in its role as a space weather monitoring agency and as a forecast/alert agent for the civilian space program. No other agency--not NASA and not the US Air Force--
is able or prepared to perform these critical functions. Moreover, if another agency were to attempt to assume the roles played by SEC, it would take an impossibly long time and cost immense amounts of money to replicate what NOAA now has in place.

In my roles in the NSF/CISM and NASA/LWS programs, I am sensitively aware
that for our research programs to reach full fruition, we need the NOAA/SEC
as an active and adequately-funded partner. Only SEC can carry our research
products forward to meet users needs. Neither NASA, NSF, nor DoD researchers
can take even the best research ideas and convert them into operational tools. Only SEC is able and willing to meet this key national need.

I urge Congress to fund NOAA/SEC at the levels requested in the President's
budget. At this level, the SEC will be able to carry out its responsibilities
in an effective and prudent way. As we are seeing at this very time in the
Sun's 11-year activity cycle, it is imperative that we have an agency that can observe the Sun and forecast its influence on human technology. To fail to have support for SEC would leave us vulnerable to space weather
in countless ways.

I would be willing to amplify on any of the points raised here. I very much hope that the Subcommittee will find a way to endorse and validate the key role for the NOAA/SEC.

Sincerely,

Dr. D. N. Baker
President, American Geophysical Union/Space Physics and Aeronomy Section
--
Daniel N. Baker
Director, Laboratory for Atmospheric and Space Physics
Professor, Astrophysical and Planetary Sciences
Phone: 303-492-4509
Fax: 303-492-6444
Campus Box 590
University of Colorado
Boulder, CO 80309

Shampaine, Adam

From: murraydryer [murraydryer@msn.com]
Sent: Wednesday, October 29, 2003 2:04 AM
To: Shampaine, Adam
Subject: Statement Re: Subcommittee on Environment, Technology, and Standards' Hearing, October 30, 2003.

To:
Mr. Adam Shampaine, Staff Member
Environment, Technology, and Standards Subcommittee
Committee on Science
2319 RHOB
202 225 8844
202 225 4438 (fax)
adam.shampaine@mail.house.gov October 28, 2003

Dear Mr. Shampaine,

Thank you for the opportunity to submit this statement to your Subcommittee's Hearing on "What is Space Weather and Who Should Forecast It?" this Thursday morning, October 30, 2003.

My views come from more than a decade in aeronautical engineering (NACA/NASA and Martin Company/Lockheed-Martin) plus four decades in "Space Weather" research (National Bureau of Standards, then NOAA) within the Space Environment Laboratory/Center. After retiring from SEC in 1994, I have a perspective of how the research and operations work in this field as I continue to work as an independent consultant with an unpaid guest worker (emeritus) position at this Center. My assumption is that the first question will be part of the discussion that will be brought out by your witnesses at this Hearing. Thus, my statement is directed to your Subcommittee's second question.

My years at SEC since 1956 have included many experiences that included interactions with various U.S., non-U.S., and international organizations. It has been transparent to me that a symbionic relationship with these organizations, with SEC's playing an ever-increasing central operational role, has developed thoughout these years. More explicitly, for example, SEC is now the forecast "voice" that works efficiently with USAF, FAA, and NASA programs as well as with the satellite arm of NOAA's spacecraft operations (e.g., the GOES series of geosynchronous satellites). What has developed, then, is an optimum (please read: cost-effective) relationship with FAA's ground-, and Air Force Weather Agency and NASA's space-programs. Thus, neither USAF (that has no mandate to support national industrial nor academic programs) nor NASA (that has no mission for operational programs) have, to my knowledge, aspirations to take over SEC's role.

A case in point is the "space weather" situation facing us at this writing on the evening of October 28, 2003, following a massive solar flare this morning. With my sponsoring colleagues [USAF/Army-funded operational project with the University of Alaska/Fairbanks and a NASA-funded "Living With a Star" research project with a small business firm, Exploration Physics International, Inc. in Huntsville, AL], I have observed our prediction window being helped and used by SEC forecasters.....together with other inputs from all over the world.....to predict, officially, the arrival on October 29th (Wednesday) of this flare's interplanetary shock wave and coronal mass ejection. That is, SEC uses state-of-the-art modeling techniques together with USAF, NASA and NOAA's ground and spacecraft observations in

real time. Will these predictions come true? We don't know yet, but SEC is at the leading edge of this learning curve. SEC makes no "sky is falling" predictions; instead, their forecasters make objective state-of-art predictions on a 24/7 schedule to the best of their ability in cooperation with groups such as those mentioned above. Their product is internationally recognized as being the world's best in the new "space weather" field.

I trust that this sense of efficient and cost-effective service to the Nation will become clear in the testimony before your Subcommittee. In conclusion, I urge the members of your Subcommittee to restore and to recommend funding, fully, SEC's budget for FY04 at the $8.2M level. Thank you for your consideration of my views.

Sincerely Yours,

Murray Dryer, Ph.D.
Space Physics Consultant
5975 South Vine Street
Greenwood Village, CO 80121
Voice: 303-798-1440
murraydryer@msn.com

Shampaine, Adam

From: Ghee Fry [gfry@expi.com]
Sent: Wednesday, October 29, 2003 5:52 PM
To: Shampaine, Adam
Subject: Statement for Subcommittee on Environment, Technology, and Standards Hearing, October 30, 2003

October 29, 2003

Mr. Adam Shampaine, Staff Member

Environment, Technology, and Standards Subcommittee

Committee on Science

2319 RHOB

Dear Mr. Shampaine,

I am submitting this statement to your Subcommittee's Hearing on "What is Space Weather and Who Should Forecast It?" being held tomorrow morning, October 30, 2003.

I am Vice President and Senior Research Physicist for Exploration Physics International, Inc., EXPI, which is a woman-owned small business that focuses on space weather research and development. With our NOAA and university partners, EXPI is developing operational space weather forecast models and products for the Air Force and NASA. We rely on data from the Space Environment Center (SEC) for our research, and SEC forecasters utilize our results to forecast space weather.

My prior experience in space weather was as an Air Force officer for 20 years providing space environmental support. I had the opportunity to see space weather from a variety of perspectives: as a space weather forecaster and systems analyst, as a staff weather officer, as a manager of science teams, and as a commander of operational flight weather units. I also served as the Deputy Assistant Secretary of the Air Force (Space) for Environmental Programs (1990-1993).

What is Space Weather? The term "space weather" refers to changes in the space environment that impact our lives. Many of our technological systems on Earth and in space respond to these changes. Space weather is

directly caused by solar activity. Disturbances in the Earth's upper atmosphere and magnetic field are driven by the Sun's sporadic outbursts of energy. Solar flares, fluctuations in the solar wind, and resulting geomagnetic storms can adversely affect many systems on Earth and in space. To understand and forecast space weather, we must understand what is happening over the entire regime from its source, the Sun, to its effects at the Earth.

Who should forecast Space Weather? With society's increasing dependence upon space technology for telecommunications, navigation, and reliable power, predicting space weather is extremely important. We are beginning to extend the lead time and improve the accuracy of our space weather forecasts. The Space Environment Center (SEC) should continue to provide space weather data gathering, analyses, specifications, alerts, warnings and forecasts. They have consistently demonstrated the scientific expertise and technical competence necessary to support the needs of academic researchers, industry and non-defense governmental agencies. They need a consistent source of funding to accomplish this mission.

Thank you for this opportunity to comment.

Sincerely,

Ghee Fry

Dr. Craig D. "Ghee" Fry, Vice President

Exploration Physics International, Inc. (EXPI)

and Visiting Principal Research Scientist, CSPAR/UAH

gfry@expi.com or fryg@cspar.uah.edu

Phone: (256) 971-4080 or (256) 824-6216

Shampaine, Adam

From: Bryn Jones [bryn.jones@solarmetrics.com]
Sent: Wednesday, October 29, 2003 9:54 AM
To: Shampaine, Adam
Cc: 'murraydryer'; Ernest.Hildner@noaa.gov; john@metatechcorp.com; Joseph.Kunches@noaa.gov
Subject: What is Space Weather and Who Should Forecast It?

Dear Mr Shampaine,

I would like to present the following statement in support of the Space Environment Center at the House Hearing on Thursday, 30 October 2003:

Statement by Captain Bryn Jones
A340 Captain and Cosmic Radiation Program Manager, Virgin Atlantic Airways Limited
Co-founder of SolarMetrics Limited, the Cosmic Radiation and Space Weather specialists for the Airline Industry
Member of United Kingdom Cosmic Radiation Advisory Group

Increased cancer risk due to cosmic radiation at aircraft altitudes is a serious issue - serious enough that European legislation exists to limit the amount of radiation exposure to Air Crews. However, everyone who flies is equally exposed, although no legislation exists to limit exposure to the general flying public. There is plenty of anecdotal evidence to show that some Frequent Flyers fly considerably more than air crew.

On the 28th October 2003, the third most powerful solar flare ever recorded unleashed significant (but currently un-quantified) increases in the radiation doses experienced at aircraft altitudes. Such increases in radiation are detrimental to the health of all air travellers, as well as having serious impacts on airline operations; including damage to aircraft avionics and onboard systems, degraded or complete loss of radio and satellite communications, and disruption of ground power sources for Air Traffic Control systems. Envisaged technological developments in aircraft and supporting ground/air/space infrastructure will make the impacts of such events on future air travel even more serious.

As I write this statement the effects of yesterday's massive solar eruption are beginning to show themselves. Specifically, aircraft in flight at the moment are completely unable to communicate by radio with each other or with Air Traffic Control, resulting in clear and present danger to the aircraft and those onboard. In addition, Air Traffic Control has just severely reduced the number of take-offs resulting in significant delays.

The comprehensive services and data provided by SEC to continually monitor our Space Weather environment, and in particular, these unpredictable solar events are vital. Without availability of SEC resources, continuing research can not effectively quantify or assess the level of risk to human health and safe flight operations. And without this research our vision for safe and secure future global air travel will not be possible.

This means that the loss of all or any of SEC's capabilities will significantly impact the safety of all those that fly.

I urge all members of the House Science Committee, the Subcommittee (on Environment, Technology, and Standards), and witnesses to insist upon continued full funding for the Space Environment Center.

Yours sincerely

Bryn Jones

Hubbell, Colin

From: J. Michael Thurman [jmthurman@centurytel.net]
Sent: Thursday, October 30, 2003 9:36 AM
To: Science Committee
Subject: Space Weather and the Atmosphere (Hearing: 30 Oct 03: For entry in the record.)
Importance: High

Greetings, Honorable Legislators.

Today, 30 October 2003, the Subcommittee on Environment, Technology and Standards will be discussing space weather and who should monitor and forecast it. Please enter this letter in the record of the Subcommittee's proceedings.

The Space Environment Center is currently co-operated by the Air Force and NOAA, though its budget come completely from appropriations to NOAA. As you consider cutting this budget again, consider what this office does for many of us, your constituents.

For those of us who fly in private or commercial aircraft, the SEC informs us about saftey and communications problems we may encounter. For example, during the solar storms that have occurred this week, the SECs infomation lets us know that we will only receive radiation equivalent to one x-ray examination not ten, or one hundred or one thousand. Why is this important? Perhaps a pregnant woman would decide not to fly if she knew that she would receive radiation equivalent to one hundred x-rays. In any case she should have the choice.

Air crews, as they check usual weather data gathered from NOAA, can determine if they will have problems with communication, navigation or other avionics gear. They can also advise their passengers of expected radiation levels. Remember the pregnant woman in the last paragraph?

Others who benefit from this data are television and radio broadcasters, cable and satellite operators, electric power utilities. Yes, honorable ladies and gentlemen of the Committee, these operations can be affected by solar weather. All of the hype in the media about power grids being knocked off-line from over a week ago can happen, especially by the X-18 class flares that have blasted earth this week. Ask these industries if space weather is important to them.

Finally, any one who uses the radio spectrum needs information about space weather. Who are these constituents? Ask the NTIA what it means to the military and other security agencies to have this information. Ask the hundreds of thousands of amateur radio licensees (this nation's emergency communication reserve) what it means to know about space weather and how it affects radio communications.

Honorable ladies and gentlemen of the Committee, know that the SEC is important to many commercial and non-commercial interests. If those interests are not important, then ask what it means to a woman to have the information to choose whether or not she boards an airliner on which she and the fetus she carries will receive one, ten, one hundred or one thousand times the radiation received during an x-ray examination.

Sincerely,

J. Michael Thurman
215 S. Seminary St.
Lamar, AR 72846
479-885-3807
jmthurman@centurytel.net

Shampaine, Adam

From: Lopez, Ramon [relopez@utep.edu]
Sent: Wednesday, October 29, 2003 12:00 PM
To: Shampaine, Adam
Cc: Lopez, Ramon
Subject: Statement for House hearing tomorrow

Mr. Adam Shampaine
Subcommittee Staff Member
Subcommittee on Environment, Technology, and Standards of the House Science Committee

Dear Mr. Shampaine,

I understand that there will be a House Hearing tomorrow at 10:00 AM, the subject of which will be "What is Space Weather and Who Should Forecast It?", and that you welcome any statements regarding this issue.

I am a professor of physics and my field is space physics, focusing on the dynamics of Earth's magnetosphere. For the past few years I have also been actively involved in space weather related research, and I am of the co-Principle Investigators for the NSF-funded Center for Integrated Space Weather Modeling. I have also been active for many years in science education and communication to the public, and in May 2002 a colleague and I published a popular science book, "Storms from the Sun", about space weather and its effects on our lives.

As you will know doubt hear, "space weather" refers generally to changes in the space environment that can negatively impact space-based or terrestrial systems upon which we depend. The first space weather event was the great magnetic storm of 1859 that knocked out telegraph comminucation in North America and Europe for the better part of a week. This week and last we have been witness to ongoing space weather as a series of explosions on the Sun have hurled clouds of electrically conducting gas and magnetic field into interplanetary space. Some of those have come in the direction of Earth.

The Space Environment Center (SEC) in Boulder, Colorado, plays an absolutely vital role in predicting the potential impact of space weather events, and communicating that information to those who could be impacted. And the group of space weather forecast "customers" will only increase in the future. The SEC is staffed with experienced scientists, with international reputations in the field, and is located in a community that has extensive space physics research resources, such as the various groups at the University of Colorado. In fact, Boulder is one of the great centers for this kind of research in the world. In order to make accurate predictions, and to continue to transition research from the still infant field of space weather into operational tools, it is critical that the SEC be maintained as a healthy, viable, and well-funded institution, and also that it remain in the Boulder area where so much space weather research in conducted. Understanding the evolution of a space weather event and the potential impact is no easy matter. ABCNews.com, in covering the story, included a quote from an astrophysicist stating that last week's CME did not have a great effect because it struck the Earth's magnetic field with a "glancing blow". This is not correct. The reason that last week's CME did not cause a large magnetic storm, despite the fact that it hit Earth's magnetosphere quite solidly, is beacuse the orientation of the magnetic field in the cloud did not allow for effective energy transfer from the cloud to the Earth's magnetosphere. This case illustrates the kind of very specialized knowledge that one must have in order to understand, and eventually predict, such events. Therefore I see no alternative to maintaining the SEC as a vibrant instituion, deeply connected to the

forefront of research, if this nation is to retain a space weather prediction capability and improve it in the future.

Sincerely,

Ramon E. Lopez

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Dr. Ramon E. Lopez
C. Sharp Cook Distinguished Professor
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University of Texas at El Paso
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****

Hubbell, Colin

From: Rob Sobkoviak [k9nyo@yahoo.com]
Sent: Wednesday, October 22, 2003 1:31 PM
To: Science Committee
Subject: Space Environment Center

To:
House of Representatives Committee on Science
Subcommittee on Environment, Technology, and Standards
Hon. Vernon J. Ehlers, Chairman
2320 Rayburn House Office Building,
Washington, DC 20515

From:
Robert Sobkoviak
508 N. Fox River Street
Plainfield, IL 60544

Congressman Ehlers,

I would like these comments heard at the October 30, 2003 hearing on NOAA funding for the Space Environment Center and entered into the public record.

I am an amateur ("ham radio") radio operator, and I am a regular user of the space weather forecasts provided by the NOAA's Space Environment Center. These reports refer to solar and geomagnetic activity that influences the Earth's ionosphere.

Activity in the ionosphere determines how radio waves travel on the High Frequency ("shortwave") band, used by international broadcasters, ham radio operators, scientists and the military, among others. These reports are vital in predicting band conditions as well as times when these frequencies are unusable.

I urge you to continue funding the NOAA adequately so that the SEC can continue its work.

Best Regards,

Robert Sobkoviak
Amateur Radio Station K9NYO
Plainfield, Illinois

Shampaine, Adam

From: Webb David F Contr AFRL/VSBX [David.Webb@hanscom.af.mil]
Sent: Friday, November 07, 2003 3:33 PM
To: Shampaine, Adam
Cc: Webb David F Contr AFRL/VSBX
Subject: attention: Hearing: What is Space Weather and Who should forecas t it - 30 Oct 03

Dear Mr. Shampaine;

I understand you are the contact who can get statements concerning the above hearing inserted into the record for the hearing. My statement follows:

On September 5 the U.S. Senate Appropriations Committee passed a bill (S.1585) that would eliminate all funding in fiscal year 2004 for NOAA's Space Environment Center (SEC) in Boulder, Colorado. In July the House of Representatives passed their version of the bill that cut SEC funding to $5.2 million, 40% below the FY02 levels and below the President's request of $8.3 million. Once the full Senate passes the bill, a conference committee will meet to forge a final bill for the President's signature. As a research scientist working in the important area of space weather and its mitigation, I strongly urge you to work to reverse this action and restore
SEC's funding to the level of the President's FY04 Budget Request, $8.3 million.

The Space Environment Center provides a range of services to the Nation related to space weather phenomena, including real-time monitoring and forecasting of solar and geophysical events, conducting research in solar-terrestrial physics, and developing techniques for forecasting solar and geophysical disturbances. SEC jointly operates the Space Weather Operations Center with the U.S. Air Force and serves as the national and world warning center for disturbances that can adversely affect astronauts and satellites working in the space environment. SEC is the government's official source for alerts and warnings of disturbances and the primary provider of
the Nation's space weather service. Customers include the DoD, NASA, FAA, airlines, operators of electric power grids, communicators, satellite operators, the National Space Weather Program, and commercial providers of value-added space weather services. Partnering with researchers funded by NSF, NASA, and the DoD, SEC is the place where much of the nation's $100s of millions annual investment in the National Space Weather Program and in space physics research is applied for the benefit of commerce, defense, NASA spaceflight, and individual taxpayers. Indeed, restoring SEC's funding is cheap insurance against the lives of astronauts in space and
the $100s of billions of military and civilian assets in Earth orbit.

The Senate Appropriations Committee explains its termination of funding for SEC and space weather in NOAA tersely as "Solar observation. - The "Atmospheric" in NOAA does not extend to the astral. Absolutely no funds are provided for solar observation. Such activities are rightly the bailiwick of the National Aeronautics and Space Administration and the Air Force." There is no evidence to suggest that either NASA or the Air Force would agree to take over this vital space weather function. Therefore, passage of this cut effectively would eliminate the Nation's civilian space weather service, requiring its reconstitution within another agency at a later date and likely at higher cost.

I urge your subcommittee and Congress to work to avoid this catastrophic reduction in this Nation's space weather capability by restoring SEC's funding to the level of the President's FY04 Budget Request, $8.3 million.

Thank you.

Sincerely,

David Webb

David F. Webb
ISR; Boston College
Tel.: 781-377-3086 Fax: 781-377-3160
E-mail: webbdf@comcast.net